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# INFLUENCES OF METEORIC ASTRONOMY ON EVOLUTION.*

BY

CHARLES P. OLIVIER, PH.D.,

Professor of Astronomy and Director of the Flower Observatory, University of Pennsylvania.

*Mr. President, Members of The Franklin Institute, Ladies and Gentlemen:* It is a real pleasure to have the honor of talking to you tonight on a comparatively neglected branch of astronomy, here in The Franklin Institute, which has seen science in America grow from very humble beginnings to its present commanding position. But the important part played in this development by men connected with The Franklin Institute is too well known to all of you to need further mention by me. From a personal standpoint I am glad to speak here, so soon after my arrival in Philadelphia to take up my residence in your city. Because it was before the American Philosophical Society down by Independence Hall that, in 1911, I made what might be called my scientific début, being permitted to read a résumé of my thesis which was afterwards published in full by that Society. It may interest you to know that it was my first extensive publication on meteoric astronomy, the very subject of our talk this evening.

Before it is possible to come to an intelligent conclusion regarding any scientific hypothesis, the history of the subject must be briefly sketched for the benefit of those who perforce have paid only casual attention to it. Further the limits

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where apparent certainty ends and conjecture begins should be made very clear. To do this properly, enough must be said about the data, which are available, so that others may readily weigh their relative accuracy. It is scarcely necessary before an audience of scientists to add that any conclusions reached by me—or in general by any individual—are perforce based also upon the results of many others.

Great Bolide of September 12, 1923, by Josef Klepesta.
*From "Meteors" by C. P. Olivier, Williams & Wilkins Co., Baltimore, Md.*

Before giving any description of phenomena connected with meteoric astronomy it should be stated that the general term "meteor" is used to cover three classes of bodies. First and most common the ordinary shooting star or, technically, meteor; secondly the fireball or super-shooting star, sometimes called bolide; and thirdly the meteorite,

which is merely a fireball large enough to survive its fiery passage through our atmosphere and reach the ground in one or more solid pieces. Obviously the definitions are loose: for what one man might call a large meteor, another would call a small fireball. Nevertheless, when interpreted with common sense, the terms are valuable.

The Sharps, Virginia, Meteorite, of April 1, 1921, by Thomas L. Watson.
*From "Meteors" by C. P. Olivier, Williams & Wilkins Co., Baltimore, Md.*

Again it is certain that objects of the same material and equal mass will be merely fireballs or survive to be meteorites according to the velocity with which they meet our atmosphere. If they move slowly, they survive; if fast, they are destroyed; as kinetic energy varies as the square of the velocity. For example, the Earth moves 18 miles per second, the average cometary meteor 26 miles per second, as it passes our orbit. Then the limits of the relative velocity with which such bodies meet us are $26 \pm 18$, or 44 m/s and 8 m/s respectively. The ratio of the squares of these numbers

is 30.25 to 1. When allowance is made for the Earth's attraction, this ratio actually falls to about 20 to 1, which perhaps represents inversely their respective chances for survival as meteorites.

Iron Meteorite from Meteor Crater, Arizona, Photograph loaned by Geo. P. Merrill.
*From "Meteors" by C. P. Olivier, Williams & Wilkins Co., Baltimore, Md.*

Astronomical observations were made at least 4,000 years ago, for records stretch back that far. These refer to a variety of celestial objects. We may be quite sure that the appearance of a meteoric shower, a brilliant fireball, or the fall of a meteorite, always unexpected as they must be,

caused terror to our ancestors and were considered miraculous. We find records that meteoric stones were worshipped, during the ten centuries preceding our era, in western Asia and southern Europe. Omitting the controversial case mentioned in the Book of Joshua in the Bible, of about 1400 B.C., our earliest records of falls come from the Chinese. The first two dates are 687 and 644 B.C., with 14 others mentioned in the next six centuries. What disposition was made of these stones or exactly how they were regarded we do not know further than that the Chinese record them as coming from heaven or the sky. Fewer accounts are given by classical writers, though they say the stones were generally held to be sacred. In recent centuries the same opinion was held by various nations in the two Americas, in India, and in Japan. But the oldest preserved meteorite, whose fall is recorded, dates only from 1492. At present over 1,000 meteorites are represented in various museums, but a large percentage of the nickel-irons were not actually seen to fall. Nearly all the stone meteorites were seen to strike the ground or they would never have been found. This is because they look not unlike common rocks, and also soon disintegrate when exposed to our damp atmosphere. As for meteor showers, or the appearances of great numbers of shooting stars, we have several dozen accounts in ancient or mediæval chronicles.

Our very term "meteorology" proves that meteors were for a long time considered to be merely atmospheric phenomena like the aurora, lightning, etc. As for meteorites, scientists during the 18th century ridiculed the idea that a stone could fall from the sky, and branded as ignorant dupes or deliberate liars everyone who reported such occurrences. Their argument was simplicity itself: stones could not fall from the sky, therefore they did not. Who could ask for more? But despite the dictum of the greatest scientists (and this included every branch of natural science as well as astronomers) stones kept on falling, so in 1803 Biot was finally delegated by the French Academy to investigate the fall at l'Aigle in France, and his report carried conviction to the most opinionated of his colleagues. From that day on, meteorites took their place as respectable, if minor, members of the Solar System.

Great Bolide of August 13, 1928, by M. de Kerolyr.

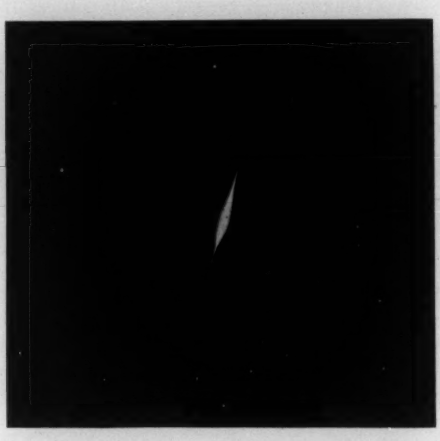
However, despite the fact that as early as 1798, in Germany, simultaneous observations had proved that meteors were from 50 to 100 miles high, when they disappeared, and that Humboldt described a wonderful shower in November, 1799, while traveling in South America, while another fine shower was seen in the United States in April, 1803, still meteors were wholly neglected by astronomers in general. Only casual mention can be found here and there in the scientific literature of the early nineteenth century. It remained for the great Leonid shower of November 13, 1833, to finally force the attention of the scientific world to the fact that here was a wholly neglected field of astronomy waiting for investigation.

This great shower of 1833 was seen as such only in the Western Hemisphere, but luckily by this time there were able men in our country who made valuable observations during its progress. We may consider this as the real birthday of meteoric astronomy. Olmsted of Yale, along with a half a dozen others elsewhere, discovered the existence of a radiant point for the Leonid meteors on this night. He however followed up his discovery by notable work and was therefore the first American to deserve a permanent place in the annals of meteoric astronomy.

Serious research work done by many culminated in the 1860's in the brilliant results of Newton and Schiaparelli. The first was able to predict successfully the return of the Leonid shower in 1866, the second proved the connection between Tuttle's Comet and the Perseid meteors which appear every August, coming to a maximum about the eleventh. The Leonids soon after were proved to follow the same orbit as Tempel's Comet, and similar relations were found for the Bielids and Lyrids. The next important event was the splendid shower in November, 1872, which at once was proved to follow the orbit of Biela's Comet. This shower again appeared in 1885, in 1892, and died out in a small one in 1899. This last was seen by the speaker, as a boy, though he did not then know its appearance had been predicted.

We therefore see a close correlation between meteor showers and comets. Let us pause to remind you that a typical comet consists of three parts, nucleus, coma, and tail.

The nucleus is not one solid mass, but a multitude of small, solid masses, of varying size. The coma must be largely gaseous, with a certain amount of the nuclear material scattered through it. The tail is made up of particles repelled from the coma, and is always directed away from the Sun. The size of these particles must be sub-microscopic.



Fireball of Fireball of June 29, 1927, by Issei Yamamoto.

It must be clearly understood that meteors cannot come from debris in comets' tails, but from larger nuclear debris. Comets therefore continually lose part of their material on each visit to the Sun. The famous Biela's Comet, for instance, seems to have been wholly dispersed since 1852.

Questions of evolution may be first properly introduced here. A few personal opinions must be pardoned, because they will clear up later statements. As the way in which the heavenly bodies evolved is, in the purely physical sense, the greatest problem offered to the human mind—the problem of the universe indeed—a complete and final solution is not to be expected. The time scale and the space scale are so immense, that even were we better acquainted with all physical laws, our solutions inevitably would be approximate.

In the present state of science contrary opinions can be offered, without possibility of definite disproof. Each theory presented probably has some truth, and certainly much error. At least this momentary advantage comes to the individual astronomer—he can use his trained imagination, if he has any, and perhaps add a little to the ultimate solution.

Being primarily interested here in our Solar System, the speaker hastens to add that in a broad sense he accepts the Planetesimal Hypothesis of Chamberlin and Moulton as giving the most satisfactory general picture of evolution. However, appearing just in time for me to hurridly read over part of it, the final book on this subject [1] by the late Prof. T. C. Chamberlin came into my hands a few days ago. While one speaks with diffidence about disagreement with such an eminent man, for I believe that the tremendous significance of his work in this line is still largely unappreciated, I cannot agree with his detailed ideas on the origins of comets and meteorites. Yet I believe that the origins of meteorites, and possibly comets, can be fully explained on ideas given earlier in his book, and that we need go to no other hypothesis than the original planetesimal. These ideas will be developed during this lecture. As for comets, he at least has given a coherent theory, a thing no other astronomer in the past has succeeded in doing. For comets are perhaps the hardest things to explain in the universe.

Briefly, his idea was that meteors and the nuclei of comets are simple chondrulites or groups of them respectively. These chondrulites are composed of matter ejected from the Sun; indeed we see eruptive prominences active on that body continually. He believed that such matter, projected into space, cooled rapidly forming what he called precipitates. These in turn aggregated into somewhat larger bodies, the primitive chondrules.

If his view is correct, the argument to be developed here would be largely wrong. But to the speaker it appears impossible that the gaseous matter thrown out from the Sun into space, as we see in the prominences, which would have little mutual gravitation due to its extreme tenuity, could so condense. Would it not rather simply tend to diffuse away

[1] "The Two Solar Families," T. C. Chamberlin, 1928.

Halley's Comet, May 1, 1910, by Heber D. Curtis.

under radiation pressure, the kinetic energy of its separate molecules, release from all external pressure, and tidal actions due to any passing body?

Unfortunately, no one can try the experiment under solar conditions, and I fear that as yet what really happens is a matter of opinion, not proof. In partial support of my own view, however, Jeffreys the distinguished English astronomer, in 1918, concluded that no planet or satellite whose present diameter is less than 1,000 km. could ever have been gaseous. This conclusion, if even approximately correct, bears on our problem.

This discussion could not properly be introduced here except that the nature of comets' nuclei, as postulated by Chamberlin, is I think disproved by the two known cases of collisions with our Earth. These are now taken up as they furnish first-hand information about the nature of comets and meteorites and their present effects on other bodies, which is evolution still in progress.

The first case is the famous Meteor Crater,[2] Arizona, a hole 4,200 feet in diameter and 600 feet in visible depth, dug out in the solid rock by the impact of an immense compact group of meterorites, which must have been the nucleus of a small comet. The proof of the impact origin we owe to the untiring labors of my friend, Mr. Daniel Moreau Barringer, a resident of Philadelphia and well known to you all. The great mass was finally located by a bore-hole 1,400 feet under the south wall, and is now being mined for. Its recovery will be of the vastest value to science and is eagerly being awaited by us all. This fell almost certainly within the past 5,000 years, probably within the past 2,000.

The second case was on June 30, 1908, in Siberia.[3] Due to the inaccessibility of the region, authentic news only reached the scientific world much later, and not until 1927 was an expedition able to reach the spot. This reported an area of 30 to 40 km. in diameter wholly devastated, the trees dead, their trunks seared as by a sudden blast of hot gases, and many lying on the ground, their tops pointing outward from the central region. Here over a large area were hundreds

[2] "Coon Mountain and its Crater," D. M. Barringer, *Proc. Acad. Nat. Sci.*, Philadelphia, 1906.

[3] *Scientific American*, July, 1928.

of "shell-holes" from one to 50 meters in diameter, but as the ground was swampy, water must have been in them. The expedition was too poorly equipped to dig out whatever masses lay in their bottoms. The waves set up by the passage through the air of these celestial visitors were so violent as to knock down men 100 km. from the edge of the devastated area, and affected barographs several hundred kilometers distant. Luckily nobody was within the area,

Microphotograph of Carleton, Texas, Meteorite, by Lewis E. Jewell.

but hundreds of reindeer, sent there to graze, perished. Here we have the example of the effects of collision with the head of another comet, certainly a small one as it was not seen out in space. There is some reason to think this was a fragment connected with Pons-Winnecte's Comet which came to perihelion in 1909. This probability is heightened by the fact that the speaker was able to prove in 1916 that certain meteors seen in May and June of that year followed the same orbit as Pons-Winnecke's Comet,[4] proving that the forces of disintegration were well at work on that body. So it appears that we have here two rather distinct forms of comets, one

[4] *Monthly Notices*, R. A. S., 77, 71, 1916.

with a very compact nucleus, with only relatively small fragments accompanying it for a few miles on either side, the other a nucleus made up of widely scattered single masses, no one of them very large.

From these examples it appears clear that both classes of nuclei must be made up of fragments of considerable size, as well as little fragments, which latter is the composition of such nuclei according to Professor Chamberlin's opinion.

The craters on the Moon are ascribed to two possible agencies: volcanic action and impact of masses of various sizes. While quite open to conviction and despite the increasing favor with which the meteoric theory is viewed, my present opinion is that while impact certainly accounts for a percentage of those visible, still there are almost insuperable difficulties in accepting the impact origin as a general explanation for lunar surface features. I freely admit great difficulties in accepting the volcanic theory also, but not quite so grave, I believe, as with the impact theory. Professor Chamberlin agreed with this viewpoint, which of course is nothing new. I have, however, been able to point out that even today there is on the unprotected lunar surface an action,[5] not unlike erosion, going on due to the continual impact of meteoric bodies of all sizes. This obvious action seems to have been formerly wholly overlooked, or certainly no one realized its consequences.

Next in order comes a brief study of the structure of meteorites. The slides thrown upon the screen illustrate their extreme complexity. It seems fairly certain that these bodies once formed part of the masses of larger ones, and that forces like those acting within the Earth caused the extreme complexity of structure you can see. Both heat and pressure played their part. We see examples of refusion and alteration, and in certain cases the introduction of metal can be proved to be subsequent to the consolidation of the stony material. In the speaker's opinion it appears impossible to assume that such actions could take place merely by the meeting of smaller particles in space, or indeed elsewhere than within a solid body of some size, which was afterwards destroyed or at least disintegrated. The idea advanced is simply this: that while 8 large and at least 1,000 small

[5] "Meteors," C. P. Olivier, 254, 1925.

planets survived the processes of evolution, to say nothing of satellites and comets, many that reached partial growth were destroyed by the very forces that built up the others. The planetary bodies at present in the Solar System merely represent the survival of the fittest.

Again, that there can be no hard and fast line of demarcation between asteroids and comets is proved, for instance, by Asteroid No. 944.[6] Its orbit is quite cometary, and if it showed either a coma or a tail would be so classed. Other asteroids have orbits of high inclination and large eccentricity, not unlike short period comets. It will be objected that we have no asteroids with retrograde motion, while half of the comets have it. But let us point out that all the very short period comets have direct motion and small inclinations. There are a few comets of medium period and retrograde motion. Cannot this be interpreted to mean that comets (or asteroids) of short period, retrograde motion, and small inclinations, had a poor chance for survival? They were, to express it crudely, swimming against the stream, when, according to hypothesis, the whole region within the orbit of Jupiter must have been filled with planetary building material. The possibility is therefore suggested that asteroids and comets had the same kind of origin. In the first case it seems probable that enough material came together under favorable circumstances for its mutual gravitation to draw it all into a compact or comparatively compact body.[7] In

[6] "Meteors," 267–8, 1925.

[7] With regard to both asteroids and satellites, it seems to have been generally tacitly assumed that they were solid, continuous bodies. But on what is this based? So far as asteroids are concerned we have no way to determine the masses of any of them, nor are we liable to do so unless in the cases of the very largest a comet should pass extremely near one of them. With satellites we are in a more favorable position, and very curious results follow in some cases. For instance the fourth satellite of Jupiter—Callisto—turns out to have a density of only 0.58. Also for the satellites of Saturn we find Minas, 0.24; Euceladus, 0.52; and Tethys, 0.54. These values are calculated from data in Table IV of "Astronomy" by Russell, Dugan and Stewart. How can such low densities be explained on the basis of a single, continuous, solid body? For it seems impossible to assume these small bodies are still in the gaseous or liquid form. Is it possible that such satellites furnish us with examples of bodies that are in constitution half way between a typical solid satellite or asteroid, and the nucleus of a typical comet? Is it possible that the variability of some asteroids and satellites could be explained on the basis of their being a fairly compact group of separate masses rather than one continuous body?

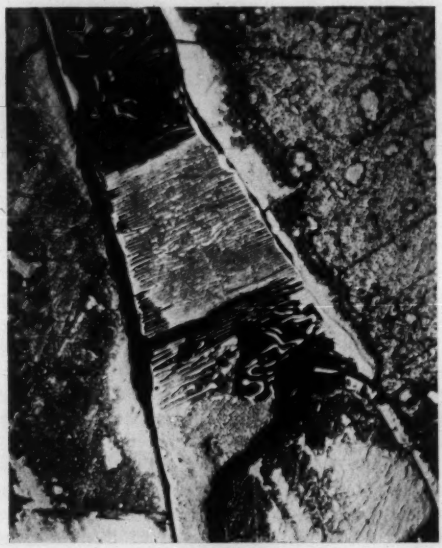
the second case, the circumstances were unfavorable and the material less. Remember that practically all asteroids we can see are within the orbit of Jupiter; we do not know about those outside. Again we find meteorites and fireballs with orbits of all inclinations. Does it not seem probable therefore that the action of Jupiter, plus collisions with other masses, did not permit retrograde asteroids of considerable size to survive? Very small ones, with orbits of high inclination, would escape discovery except under most favorable circumstances. But these actions just mentioned might well permit the survival of retrograde comets of long period, which would spend so little of their life within the critical region.

Calling up again the Meteor Crater and Siberian cases, here we have one body, that if it could have been seen at all would have looked like a tiny asteroid, the other like a tiny comet. Yet each are technically comets. Again I find that work at the Lick Observatory,[8] that just came to my notice after most of this paper was written, showed that spectrograms of asteroids are remarkably weak in the ultra-violet region and this in the opinion of the observers connects these bodies physically with the nuclei of comets. Also the presence of small retrograde satellites in the systems of Jupiter and Saturn, without the orbits of the direct moving satellites of these planets, proves that retrograde bodies of small size survive only under special conditions. So while the chain of evidence is far from complete, these various facts are certainly very significant. The probable reason we see so few cases of "stripped nuclei" of comets—to borrow a physical term—such as the Meteor Crater nucleus probably was, is that such a comet, stripped of its coma, assuming indeed it ever had one, would usually be too small to be seen at any distance from the Earth. We can by no means assume that many do not pass us annually undetected.

You will notice that no mention has been made of the great Nebular Hypothesis of LaPlace, nor of Lockyer's Meteoric Hypothesis. The first ignores meteors and one can find no place for them in it. The second starts with meteorites as the building material of the universe. As

[8] *Pop. Astr.*, 37, 31, 1929.

meteorites are very complex bodies, this seems to me to be an insuperable difficulty to its acceptance. It is almost a case of putting the cart before the horse. Also while this theory played an important part in its day, it really added nothing to meteoric astronomy proper except calling attention to these bodies. However, many eminent astronomers now consider certain nebulæ to be meteoric in composition. This may



Microphotograph of Toluca, Mexico, Meteorite, by Lewis E. Jewell.

particularly apply to the dark nebulæ. This phase of the subject is, I think, out of the direct line of our discussion and besides is as yet wholly in the conjectural stage.

A study of the paths of fireballs and meteorites by von Niessl and others has proved that many of these bodies move with a strongly hyperbolic velocity. Of one fact we are sure: a body moving with such a celocity never originated in the

Solar System, no matter what theory we choose to accept as to its origin. Please bear in mind that most important fact, as the rest of the argument depends upon it. Again a study of the structure of meteorites of all kinds shows that while they indeed contain some minerals not found on the Earth, no new element whatever can be detected. So far about half of the familiar ones have been found. This proves the chemical unity of the Universe. Next, in many cases we find meteorites moving with such velocities that they are well within the parabolic limit, in other words they just as surely originated in the Solar System as those with great hyperbolic velocities could not. We also have every reason to believe that meteorites of assorted sizes compose the nuclei of comets, which again originated in our system.

Hence we come to the conclusion: That finding meteorites which certainly originated in our system (irrespective of what theory of their evolution we accept, for that does not enter now into the argument), and finding similar meteorites which certainly came to us from without our system (which means they originated in some other distant stellar system) then a similar evolution took place there and here. This important conclusion destroys definitely (if it can be accepted as true) the uniqueness of the Solar System, and we would expect to find innumerable similar systems among the stars. For if our argument is correct meteorites and comets are the products of the same catastrophic event that gave birth to the planets themselves. We would therefore infer that planets also, not unlike our own, circulate about other stars as well as these meteorites which alone with an occasional comet can escape from their original homes and bring this message to us. That no strongly hyperbolic comet [9] has yet been observed seems purely a matter of chance, for only those which came very near indeed to our Sun could be observed from the Earth. It does not prove that such comets do not visit our system at intervals, much less never.

It is but fair now to examine the reliability of the data

[9] The discussion of comets in many books on astronomy is very misleading. An uninformed reader might infer that most comets which visited the Sun, either periodically or otherwise, came within sight of the Earth's orbit. This assumption is probably quite contrary to fact.

we have used. Obviously the velocities were the most important, and unless warned you would think they were easy enough to obtain. But due to the fact that fireballs and meteorites come unannounced their orbits must be calculated, generally, using data sent in by untrained men. Until such velocities can be gotten by instrumental means, there will always remain some doubt as to their reliability. Yet this fact comes out: those cases with the very best observations usually give higher velocities than those based on poorer material. Again Hoffmeister [10] has proved that small meteors have as a rule strongly hyperbolic velocities, basing his theory on the variation of hourly numbers, and more recently on more involved considerations. So every line of approach, at present available, gives us reason to believe that the larger percentage of all meteoric bodies comes from outer space. But the annual showers, which come from groups following comets with known periods, prove that others move in ellipses and are hence members of the Solar System and originated within it. You see, however, why we await so anxiously the development of faster photographic plates so that we may definitely test the velocities by instrumental means, on a large scale. That done, we will have no longer this weak link in the chain of argument, no matter in which direction we are finally led.

May we add that the studies of the changing speeds of meteors in our upper atmosphere, and the behavior of their trains, give us invaluable information as to its constitution and density, as yet approachable in no other way. Studies of their spectra, when available in some numbers, also will be valuable. The physical theory of meteors in our atmosphere has not yet been solved in a way generally accepted, and indeed there are numerous other problems for physicists and meteorologists as well as astronomers furnished by these little debris of evolution, as we may justly call them.

To review rapidly some of the points raised in this discussion, we will now run through a number of slides.

Finally, just as the brickbats, pieces of stone, scraps of metal, and wooden chips that lie around a newly completed house would give us an idea of how the building was erected,

[10] *Astron. Abhandlungen*, Band 4, Nr. 5.

so meteors and meteorites can give us similar information as to the evolution of the Solar System. Yet in some of the older theories there was no place for them whatever! But in the future no theory of how this wonderful masterpiece of the Creator evolved can be considered even approximately complete that does not take full account of these bodies which are so small in size but so important in the information they bring to us.

As for this talk which is just being concluded, while I have been rather bold in offering a partly new theory, knowing it has as yet so many unproved links, still, even should the theory itself eventually prove wholly unacceptable, some of the data on which it is based and the arguments brought forward in its support should have a more permanent value.

**A New Method of Developing Electricity in Quartz Crystals by the Use of Torsion.** E. P. TAWIL. (*Comptes Rendus*, Dec. 3, 1928.) Pierre Curie and his brother discovered that certain crystals when subjected to changes of pressure develop the two kinds of electricity at different parts of their surfaces-piezoelectricity. The author has found that torsion applied to quartz crystals produces a similar separation of electricity. A cylinder of quartz is made with its axis parallel to the optical axis of the crystal. The ends of the cylinder are provided with mountings one of which is kept fixed while the other is provided with a lever for torsion. As soon as the cylinder is twisted the surface of the cylinder shows everywhere an electrical charge of the same sign throughout, while the opposite charge manifests itself on the ends perpendicular to the axis. When the crystal is twisted in the opposite direction the charges are reversed. Even relaxing the torsion so that the cylinder resumes its position of equilibrium causes a reversal of the charges. It makes a difference whether the quartz rotates the plane of polarization to the right or to the left. A crystal receives a positive charge on its outer surface when it is twisted in the sense of its optical rotation. Natural crystals of quartz show a similar effect. From the sign of the electricity set free by torsion it is possible to determine in which sense the crystal rotates the plane of polarization.

In applying torsion care must be exercised to avoid bending the quartz, for the author finds that this also brings about a development of electricity. For the effect due to torsion he suggests the name 'strepho-electricity.' Roentgen in 1889 investigated the effect of torsion on crystals but failed to detect the phenomena above described. G. F. S.

**Are Characteristic X-Rays Polarized?** E. O. WOLLAN. (*Proc. Nat. Acad. Sci.*, Nov., 1928.) Barkla in 1905 showed that the general radiation from an X-ray tube is partially polarized. In 1926 Bishop made the same claim for the characteristic radiation. The importance of the matter justifies the repetition of the investigation. This was carried out but with a method different from that used by Bishop. The conclusion is that "the K lines of molybdenum are not polarized in excess of one per cent." Bearden has recently published the results of his investigation of the same problem. They agree with those of the present paper. G. F. S.

# ON THE THEORY OF ELECTRON SCATTERING IN GASES.

BY

ALLAN C. G. MITCHELL, Ph.D.,

Fellow, Bartol Research Foundation of The Franklin Institute.

BARTOL RESEARCH FOUNDATION

Communication No. 38.

A GENERAL wave-mechanical theory of collisional processes has been developed by Born [1] and applied by Wentzel [2] to the scattering of alpha-particles by heavy atoms, and by Elsasser [3] to collisional processes in atomic hydrogen. Recently Sommerfeld [4] has applied the method to the scattering of electrons in argon and has found agreement with the experimental results.

To carry out the calculation it is necessary to know the potential of the atom $v(r)$ as a function of the distance from the nucleus. Wentzel first assumed the potential of an atom of atomic number $Z$ to be given by the Coulomb law $v(r) = Ze/r$, neglecting the effect of the electrons around the nucleus but found that this led to integrals which would not converge. On assuming the potential function to be $v(r) = Ze/re^{-r/R}$, where $R$ is of the order of magnitude of an atomic radius, he was able to obtain a scattering formula which, for alpha-particles, agreed with the Rutherford scattering law. On the other hand Elsasser found the potential of the hydrogen atom in terms of its eigenfunctions, the potential for the hydrogen atom in its normal state being similar to that used by Wentzel, thus justifying his assumption, and showed that a scattering law for atomic hydrogen could be obtained. Finally, Sommerfeld considered scattering from other atoms by treating all the electrons of the atom as united in the $K$-shell without mutually influencing each other. "The action of these electrons toward the outside would then

[1] M. Born, *ZS. f. Physik*, **37**, 863; **38**, 803 (1926).

[2] G. Wentzel, ibid., **40**, 590 (1927).

[3] W. Elsasser, ibid., **45**, 522 (1927).

[4] A. Sommerfeld, "Atombau und Spektrallinien," Wellenmech. Ergänzungsband, pp. 226 et seq.

be represented wave-mechanically by the $Z$-fold electron cloud of hydrogen in its normal state, whose charge density is

$$\rho = \frac{eZ^4}{\pi a^3} e^{-2r(Z/a)},$$

where $a$ is the radius of the first Bohr circle." He then showed that the potential energy of an electron in the field of the atom is

$$V(r) = -e^2 Z \left(\frac{1}{r} + \frac{Z}{a}\right) e^{-2r(Z/a)}. \qquad (1)$$

By using this potential energy in the Born collision equations he arrived at a scattering formula, which for high velocity alpha-particles and for not too small scattering angles, agrees with the Rutherford scattering law. The formula also agrees with the experiments of Kirchner [5] on the scattering of electrons in argon (elastic collisions). It will be noted that expression (1) for the potential energy takes into account shielding by the electrons of the atom.

It is the purpose of this paper to carry through the calculations using a somewhat different method of obtaining the potential of the atom at a distance $r$ from the nucleus. Thomas [6] and Fermi [7] have recently shown that if the electrons of an atom of atomic number $Z$ be considered to be a perfectly degenerate gas in the sense of the Fermi statistics,[8] the potential at a distance $r$ from the nucleus is given by

$$v = \frac{Ze}{r} \Phi\left(\frac{r}{\mu}\right), \qquad (2)$$

where

$$\mu = \frac{3^{2/3}h^2}{2^{13/3}\pi^{4/3}me^2Z^{1/3}}$$

($m$ = mass of electron).

This function $\Phi(r/\mu)$ is unity when $r$ is zero and decreases to zero for increasing $r$, such that for distances a little greater than the atomic radius the potential will be zero. No

[5] F. Kirchner, *Ann. der Phys.*, **83**, 969 (1927).
[6] L. H. Thomas, *Proc. Cambridge Phil. Soc.*, **23**, 542 (1926).
[7] E. Fermi, *ZS. f. Phys.*, **48**, 73 (1928).
[8] E. Fermi, ibid., **36**, 902 (1926).

analytical expression is known for the function $\Phi$ over its whole range, but a table of values is given by Fermi.[9] He has used this function to calculate the Rydberg correction terms of the alkali atoms,[10] generally thought of as due to the shielding of the nonradiating electrons. In this paper we shall consider this potential function as giving the true potential of an atom at a distance $r$ from the nucleus, inclusive of shielding, and use the potential energy derived therefrom in conjunction with the Born collision theory to calculate the scattering from different atoms.

To calculate the scattering of an electron by an atom situated at $O$ (Fig. 1), we consider a plane wave for an electron

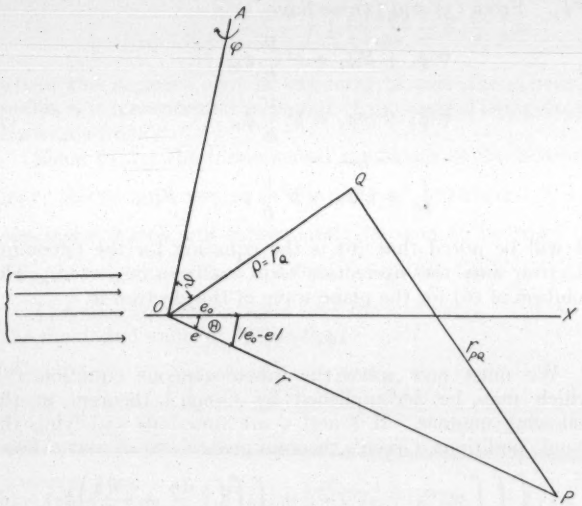



FIG. 1.

approaching the atom from the negative X-direction. The wave equation for the total system, electron plus atom, is

$$\nabla^2\psi + \frac{8\pi^2 m}{h^2}(E - V)\psi = 0. \qquad (3)$$

[9] See ref. 6, p. 75.

[10] E. Fermi, *ZS. f. Phys.*, **49**, 550 (1928).

We consider $V$, the potential energy of the system, as a perturbation term and write

$$\psi = \psi_0 + \psi_1 + \cdots. \tag{4}$$

Substituting in (3) and writing $k^2 = \frac{8\pi^2 mE}{h^2}$ we have

$$\nabla^2(\psi_0 + \psi_1 + \cdots) + k^2\left(1 - \frac{V}{E}\right)(\psi_0 + \psi_1 + \cdots) = 0, \tag{5}$$

where

$$\nabla^2\psi_0 + k^2\psi_0 = 0, \tag{6}$$

since $V\psi_1$ is to be neglected in comparison with $\nabla^2\psi_0$ and $k^2\psi_0$. From (3) and (4) we have

$$\begin{aligned} \nabla^2\psi_1 + k^2\psi_1 &= k^2\frac{V}{E}\psi_0, \\ \nabla^2\psi_2 + k^2\psi_2 &= k^2\frac{V}{E}\psi_1, \\ &\cdots\cdots\cdots \\ \nabla^2\psi_n + k^2\psi_n &= k^2\frac{V}{E}\psi_{n-1} = F_{n-1}. \end{aligned} \tag{7}$$

It will be noted that (6) is the equation for the oncoming electron since the interaction term has been neglected. The solution of (6) for the plane wave of the electron is

$$\psi_0 = e^{ikz}.$$

We must now solve the inhomogeneous equation (7), which may be accomplished by Green's theorem in the following manner. If $\xi$ and $\eta$ are functions satisfying the usual conditions, Green's theorem gives

$$\int\int\int (\xi\nabla^2\eta - \eta\nabla^2\xi)d\tau = \int\int\left(\xi\frac{\partial\eta}{\partial n} - \eta\frac{\partial\xi}{\partial n}\right)d\sigma. \tag{8}$$

We shall let

$$\xi = \frac{e^{ikr}}{r}, \tag{9}$$

a function satisfying the homogeneous equation

$$\nabla^2\xi + k^2\xi = 0, \tag{10}$$

and

$$\eta = \psi_n. \tag{11}$$

We take the origin of $r$ as the point $P$, at which we shall seek the value of $\psi_n$. We shall take for our boundary of integration two surfaces, one a sphere of radius $R$ about $P$, which sphere shall eventually be made infinite, and for the other boundary a small sphere of radius $r_0$, which shall eventually be made zero. Substituting (9) and (10) in (8) we obtain

$$\begin{aligned}\iiint \frac{e^{ikr}}{r}(\nabla^2\psi_n + k^2\psi_n)d\tau = &\iint\left(\xi\frac{\partial\psi_n}{\partial r} - \psi_n\frac{\partial\xi}{\partial r}\right)d\sigma \\ &- \iint_{r_0}\left(\xi\frac{\partial\psi_n}{\partial r} - \psi_n\frac{\partial\xi}{\partial r}\right)d\sigma,\end{aligned} \tag{12}$$

where the negative sign in the integral over the sphere of radius $r_0$ is incorporated to permit of the normal being drawn outwards from $P$.

Since $\psi_n$, by the fundamental conditions of the Schroedinger theory must vanish to the order of $\frac{1}{r\epsilon}$, where $\epsilon > 0$ (a conclusion which will subsequently be seen to be true) the integral over the surface $R$ will vanish to the order $\frac{1}{r\epsilon}$.

Consider now the integral over the surface $r_0$. Let $M$ be the maximum value of $\partial\psi_n/\partial r$ then

$$\iint_{r_0}\frac{e^{ikr}}{r}\frac{\partial\psi_n}{\partial r}d\sigma < \frac{e^{ikr_0}}{r_0}M4\pi r_0^2$$

and is zero in the limit. Now

$$\iint_{r_0}\psi_n\frac{\partial\xi}{\partial r}d\sigma = \iint_{r_0}\psi_n e^{ikr}\left(\frac{ik}{r} - \frac{1}{r^2}\right)4\pi r^2 dr = -4\pi\psi_n$$

in the limit.

Hence (12) becomes

$$\psi_n = -\frac{1}{4\pi}\iiint\frac{e^{ikr}}{r}(\nabla^2\psi_n + k^2\psi_n)d\tau'$$

and remembering (7) we obtain

$$\psi_n = -\frac{1}{4\pi}\iiint F_{n-1}(r_Q)\frac{e^{ikr_{PQ}}}{r_{PQ}}d\tau'. \tag{13}$$

Taking the first approximation we have

$$\psi_{1(P)} = -\frac{k^2}{4\pi E}\iiint V(r_Q)\frac{e^{ikr_{PQ}}}{r_{PQ}}e^{ikz_Q}d\tau'. \tag{14}$$

From Fig. 1 we have

$$r_{PQ} = |\mathbf{r} - \mathbf{r}_Q| = [\mathbf{r}^2 + 2\mathbf{r}\cdot\mathbf{r}_Q + \mathbf{r}_Q{}^2]^{1/2}.$$

If $r \gg r_Q$ then

$$\begin{aligned} r_{PQ} &= r\left(1 - \frac{1}{r^2}\mathbf{r}\cdot\mathbf{r}_Q\right) \\ &= r - \mathbf{e}\cdot\mathbf{r}_Q, \end{aligned} \tag{15}$$

where $\mathbf{e}$ is a unit vector in the direction $r$. We also write

$$x_Q = \mathbf{e}_0\cdot\mathbf{r}_Q \tag{16}$$

where $\mathbf{e}_0$ is a unit vector in the direction $X$. Equation (14) becomes

$$\psi_{1(P)} = -\frac{k^2}{4\pi E}\frac{e^{ikr}}{r}\iiint V(r_Q)e^{ik(\mathbf{e}-\mathbf{e}_0)\cdot\mathbf{r}_Q}d\tau'. \tag{17}$$

We now change to polar coördinates taking $OA$, parallel to $|\mathbf{e}_0 - \mathbf{e}|$, as the polar axis, $\varphi$ as the longitude and $\theta$ as the co-latitude. Then

$$\rho = r_Q \tag{18}$$

$$(\mathbf{e}_0 - \mathbf{e})\cdot\mathbf{r}_Q = {}^Q|\mathbf{e}_0 - \mathbf{e}|\rho\cos\theta. \tag{19}$$

If now we introduce the scattering angle $\Theta$, we see from the figure

$$|\mathbf{e}_0 - \mathbf{e}| = 2\sin\frac{\Theta}{2}. \tag{20}$$

Making the above substitutions (17) becomes

$$\psi_{1(P)} = -\frac{k^2}{4\pi E}\frac{e^{ikr}}{r}\int_0^{2\pi}\int_0^{\pi}\int_0^{\infty} V(\rho)e^{i2k\sin\Theta/2\rho\cos\theta}\rho^2 d\rho\sin\theta d\theta d\varphi. \tag{21}$$

We now use the potential energy derived from the Fermi

statistics, which is

$$V(\rho) = -\frac{Ze^2}{\rho}\Phi\left(\frac{\rho}{\mu}\right) \tag{22}$$

for an electron at a distance $\rho$ from the nucleus. Equation (21) then becomes

$$\psi_{1(P)} = \frac{k^2}{4\pi}\frac{Ze^2}{Er}e^{ikr}\int_0^{2\pi}\int_0^{\pi}\int_0^{\infty}\Phi\left(\frac{\rho}{\mu}\right)e^{i2k\rho\sin\Theta/2\cos\theta}\rho d\rho\sin\theta d\theta d\varphi. \tag{23}$$

We first carry out the integration with respect to $\theta$ keeping $\rho$ constant. Writing $\delta = 2k\rho\sin\Theta/2$ we have

$$\int_0^{\pi} e^{i\delta\cos\theta}\sin\theta d\theta = \frac{2}{\delta}\sin\delta, \tag{24}$$

and (23) becomes after integrating with respect to $\varphi$,

$$\psi_{1(P)} = \frac{k}{2E}\frac{Ze^2}{\sin\frac{\Theta}{2}}\frac{e^{ikr}}{r}\int_0^{\infty}\Phi\left(\frac{\rho}{\mu}\right)\sin\left(2k\rho\sin\frac{\Theta}{2}\right)d\rho. \tag{25}$$

The analytical expression of $\Phi(\rho/\mu)$ is not known, hence the integration of (25) must be carried out graphically. We form the quotient $\left|\frac{\psi_1}{\psi_0}\right|^2$, and remembering that $|\psi_0|^2 = 1$ we obtain

$$P = \left|\frac{\psi_1}{\psi_0}\right|^2 = \left[\frac{kZe^2}{2Er}\right]^2\frac{1}{\sin^2\frac{\Theta}{2}}\left[\int_0^{\infty}\Phi\left(\frac{\rho}{\mu}\right)\sin\left(2k\rho\sin\frac{\Theta}{2}\right)d\rho\right]^2. \tag{26}$$

*Equation* (26) *may be interpreted as the number of particles per unit solid angle which are scattered through an angle* $\Theta$ *in relation to the number which fall on the atom.*

We shall now compare this with the expression obtained by Sommerfeld using the Born method. He obtains

$$P = \left[\frac{e^2Z}{4Er}\right]^2\left[\frac{1}{\sin^2\frac{\Theta}{2}+\alpha^2} + \frac{\alpha^2}{\left(\sin^2\frac{\Theta}{2}+\alpha^2\right)^2}\right]^2, \tag{27}$$

where $\alpha = \frac{Z}{ak}$; $a$ = radius of first Bohr circle. It will be

noted that the above formula gives exactly the Rutherford scattering law for alpha-particles if we neglect $\alpha^2$ in comparison to $\sin^2 \Theta/2$ and if we introduce the proper factor into the constant to take care of the double charge of the alpha-particle. It has been shown by Wentzel that for alpha-particles and heavy nuclei $\alpha^2$ may be neglected in comparison to $\sin^2 \Theta/2$ for not too small angles of scattering. On the other hand equation (27) gives for $\Theta = 0$

$$P = \left[\frac{e^2 Z}{4Er}\right]^2 \frac{4}{\alpha^2}, \tag{28}$$

i.e., a finite number of particles scattered at $\Theta = 0$ instead of an infinite number as given by the Rutherford law.

Kirchner has measured the number of electrons of 10 to 40 kv. energy scattered in argon by the Wilson cloud expansion chamber method and the results are in good agreement with expression (27). The number scattered at $\Theta = 0$ is finite and can be calculated from the value of $\alpha^2$ given above.[11]

We have now to investigate whether our expression (26), derived on the assumption that the potential in the atom is that given by the Fermi statistics, leads to a finite number of particles scattered at $\Theta = 0$. It will be readily seen that on putting $\Theta = 0$ (26) results in an indeterminate form. Differentiation of both numerator and denominator yields a second

[11] What Kirchner actually measured was the number of electrons scattered through angles greater than $\Theta$, which is given by

$$N = C \int_{\Theta}^{\pi} \left[\frac{1}{\sin^2 \frac{\Theta}{2} + \alpha^2} + \frac{\alpha^2}{\left(\sin^2 \frac{\Theta}{2} + \alpha^2\right)^2}\right]^2 \sin \Theta d\Theta.$$

On using the correct value of $\alpha^2$ (calculated for an atom of atomic number $Z$ and for electrons of a given velocity), the experimental data were found to fit the theoretical curve (see curves in Sommerfeld's book p. 225). Unfortunately, (26) does not readily admit of the integration performed above, owing to incomplete knowledge of the function $\Phi(x)$, hence we cannot expect to get numerical agreement with experiment. Although it is very difficult to perform the integration indicated in Note 11, one can at least get an indirect comparison with experiment by comparing the results obtained from (27) with those obtained from (26), after correct substitution of the constants involved. A comparison has been made, making use of a graphical integration of (26), and the results are to appear shortly in the Proceedings of the National Academy.

indeterminate form

$$P_{\omega=0} = \frac{2kC}{\sin\omega}\left[\int_0^\infty \Phi\left(\frac{\rho}{\mu}\right)\sin(2k\rho\sin\omega)d\rho\right] \times\left[\int_0^\infty \rho\Phi\left(\frac{\rho}{\mu}\right)\cos(2k\rho\sin\omega)d\rho\right]$$

where

$$C = \left[\frac{e^2Zk}{2Er}\right]^2; \quad \omega = \frac{\Theta}{2}.$$

Finally on differentiating both numerator and denominator a second time and placing $\omega = 0$ we obtain

$$P_{\omega=0} = 4k^2C\left[\int_0^\infty \rho\Phi\left(\frac{\rho}{\mu}\right)d\rho\right]^2. \tag{29}$$

We now make the substitution $x = \rho/\mu$, then

$$P_{\omega=0} = 4k^2\mu^4C\left[\int_0^\infty x\Phi(x)dx\right]^2. \tag{30}$$

Fermi [9] gives a table for $\Phi(x)$ for values of $x$ from 0.00 to 20.0. $\Phi(x)$ is given by the approximate formula [6]

$$\Phi(x) = \frac{144}{x^3\left(1+\frac{1}{x^\lambda}\right)^4},$$

where $\lambda$ (about $\frac{3}{4}$) is an arbitrary constant. For very large values of $x$ the above equation becomes $\Phi = \frac{144}{x^3}$. The integral $\int_0^\infty x\Phi(x)dx$ will converge and hence a finite value of $P_{\omega=0}$ will be obtained from equation (30), in agreement with the results obtained using the other theory.

Finally, we shall show that the general form of the scattering curves is the same on the basis of the two theories, namely that the scattering is a maximum for $\omega = 0$ and a minimum for $\omega = \pi/2$. Consider, first, equation (27). By taking the first and second derivative of $P$ with respect to $\omega$ (where $\omega = \Theta/2$), and applying the criteria for maxima and minima, it is easily seen that $P$ has a maximum at $\omega = 0$ and

a minimum at $\omega = \pi/2$. Similarly for equation (26), based on the Fermi potentials, we obtain for the first derivative

$$\frac{dP}{d\omega} = \frac{2C\cos\omega}{\sin^2\omega}\left[\int_0^\infty \Phi \sin(2k\rho\sin\omega)d\rho\right] \cdot \left\{-\frac{1}{\sin\omega}\left[\int_0^\infty \Phi\sin(2k\rho\sin\omega)d\rho\right] + 2k\left[\int_0^\infty \rho\Phi\cos(2k\rho\sin\omega)d\rho\right]\right\}.$$

This will obviously be zero for $\omega = \pi/2$. For $\omega = 0$ the conditions for $\frac{dP}{d\omega} = 0$ are

$$\frac{1}{\sin^2\omega}\left[\int_0^\infty \Phi\sin(2k\rho\sin\omega)d\rho\right] \neq \infty \qquad \text{at} \qquad \omega = 0 \tag{31}$$

and

$$\frac{1}{\sin\omega}\left[\int_0^\infty \Phi\sin(2k\rho\sin\omega)d\rho\right] = 2k\int_0^\infty \rho\Phi\cos(2k\rho\cos\omega)d\rho. \tag{32}$$

The first condition gives an indeterminate form, which on evaluating gives

$$\frac{1}{\sin^2\omega}\left[\int_0^\infty \Phi\sin(2k\rho\sin\omega)d\rho\right] = 2k^2\left[\int_0^\infty \rho^2\Phi\sin(2k\rho\sin\omega)d\rho\right].$$

$$= 0 \qquad \text{for} \qquad \omega = 0.$$

The second condition likewise is fulfilled for $\omega = 0$, since on evaluating the indeterminate form on the left hand side of (32) we obtain the right hand side of (32) for $\omega = 0$. $P$ is obviously a maximum for $\omega = 0$. To show that it is a minimum for $\omega = \pi/2$ we take the second derivative with respect to $\omega$

$$\frac{d^2P}{d\omega^2} = -\frac{2C}{\sin\omega}\left\{\left[\int_0^\infty \Phi\sin(2k\rho\sin\omega)d\rho\right]\right\} \times \left\{-\frac{1}{\sin\omega}\left[\int_0^\infty \Phi\sin(2k\rho\sin\omega)d\rho\right]\right.$$

$$+ 2k\left[\int_0^\infty \rho\Phi \cos(2k\rho \sin\omega)d\rho\right]\Bigg\} + A\cos\omega(\cdots).$$

The last term indicates a number of factors which are multiplied by $\cos\omega$ and which vanish for $\omega = \pi/2$. The condition that $P$ should have a minimum at $\omega = \pi/2$ is

$$-\frac{1}{\sin\omega}\left[\int_0^\infty \Phi \sin(2k\rho \sin\omega)d\rho\right] + 2k\left[\int_0^\infty \rho\Phi \cos(2k\rho \sin\omega)d\rho\right] > 0.$$

A numerical integration of the integrals involved shows that this condition is fulfilled.

In conclusion we may summarize the results of this investigation as follows. By using the Fermi statistical potentials in conjunction with the Born collision theory, we have derived a formula for the scattering of electrons in gases. The scattering formula here developed gives a finite number of particles scattered at small angles, $\Theta = 0$; the maximum scattering occurs at $\Theta = 0$, and the minimum at $\Theta = \pi$. This is in qualitative agreement with the results obtained by Sommerfeld, by considering all the electrons to be gathered together in the $K$-shell and treating the result as a hydrogen-like atom. The method of Sommerfeld, although it gives results in agreement with experiment, seems somewhat illogical in the light of our knowledge of the periodic table. On the other hand, the argument presented in this paper appears to be logical in so far as the calculation of atomic fields by the method of Fermi is logical. The latter, however, seems to be in agreement with the laws of the periodic system, since Fermi has used it to calculate in which atoms the $s$, $p$, and $d$ terms appear and has found agreement with the facts. The method of Fermi has the disadvantage of mathematical complexity which does not allow us to readily calculate numerical values of scattering which can be compared with experiment.

The writer wishes to acknowledge his indebtedness to his colleagues of the Bartol Research Foundation, in particular to Prof. W. F. G. Swann and Dr. A. Bramley for many helpful suggestions in connection with this work.

**The Ellipticity of the Earth is not a Proof of a Former Liquid State.** JOHN F. HAYFORD. (*Am. J. Science*, Aug., 1928.) "The idea is often expressed, even by physicists in good standing, that the observed ellipticity of the earth is a proof of a former liquid state. I am here to challenge this idea. The challenge is not new, nor are the ideas I shall express new. But the frequency with which this mistaken idea is repeated shows that it should be challenged again, and in a direct and positive manner." The error seems to rest on an underestimate of the stress-differences that would be called into action by a departure of the actual ellipticity of the earth from the ellipticity that corresponds to its present rate of rotation. Sir George Darwin has subjected this matter to computation and "finds that if the present ellipticity differs from the ellipticity due to present rotation by one-eighth part, the stress-differences due to this cause which necessarily exist in the earth are one-half ton per square inch over the whole surface of the earth, are as a rule greater the greater is the depth below the surface, and are four tons per square inch at the center of the earth." The author now proceeds to consider the physical properties of granite and the safe stresses to which it may be subjected. The conclusion is that, were the earth composed of good granite throughout, it could not withstand the stress-differences cited above but would yield and assume a changed shape. Of all materials in the earth's crust granite is one of the strongest. A heterogeneous mass made up of granite and weaker constituents would yield more readily than granite alone. Moreover the presence of high temperature at the center of the earth and the persistance of the deforming forces through long periods assist in bringing about the same result. The author holds that "the departure of the actual ellipticity from that due to rotation must always have been and is now less than 1/160 part, even if the earth has always been and is now solid throughout." This is so small a part of the small ellipticity of the earth that it may well be masked by other factors and cannot be trusted as a basis for conclusions on the strength of the earth. Hence "the evidence afforded by the observed ellipticity of the earth is not sufficient to prove that the strength of the material in the interior of the earth, available to resist stress-differences, is now, or ever has been, so small as to justify the statement that said material is now or ever has been, a liquid."

G. F. S.

# THE HERSCHEL EFFECT.*

BY

A. P. H. TRIVELLI.

## HISTORY.

In 1840 Sir John F. W. Herschel published in the *Philosophical Transactions* an observation he had made on August 27, 1839:[2]

"A highly concentrated spectrum having been formed on muriated paper, and kept for some time on the same spot, a coloured picture was formed. On examining this picture by dispersed daylight, I now for the first time noticed, that in all that part of the paper on which the full red of the spectrum had fallen, there was an appearance of whiteness, a sort of white prolongation of, or appendage to, the dark photographic impression, contrasting itself with the general ground of the paper which, under the influence of dispersed light from passing clouds, sky, *etc.*, had acquired a very sensible discolouration. This discolouration had, therefore, as would appear, been counteracted by the red rays of the spectrum, which are, therefore, by no means to be regarded as inactive, but rather, at least in this instance, as exciting an action of an opposite nature to that of the blue, violet, and lavender rays." On the next page he wrote about the conservative whitening or oxidating action of the red rays.

It is evident that what we now term the Herschel effect is not the effect observed by Herschel. In recent literature, most authors regard the Herschel effect as a bleaching-out of the latent image by red or infra-red radiation. Originally, it was an effect on the direct visible photochemical image, observed on silver chloride. Since the visible photochemical decomposition of the silver halides shows so many analogies to the action of the latent image, there is no objection to acceptance of the same name for the corresponding effect

* Communication No. 383 from the Kodak Research Laboratories.

[1] *On the Chemical Action of the Rays of the Solar Spectrum, Etc.*, London 22 (1840). (Reprint.)

with the latent image. As we distinguish between the visible decomposition of the silver halides and the latent image, we shall have to distinguish between the visible Herschel effect and the latent Herschel effect. This paper deals with the latent Herschel effect only.

Herschel's explanation of the effect as an oxidation of the photochemical decomposition product of silver chloride is in agreement with the regression concept held by many of the present investigators, who mention Claudet as the first to explain the effect in this way.

It is unnecessary to give further history of the Herschel effect, since Lüppo-Cramer [2] has recently given a thorough account of it with a complete bibliography.

### INTRODUCTION.

The investigation of the Herschel effect was begun, in these Laboratories, for several reasons: (1) For practical application to infra-red photography; (2) to obtain direct positives and duplicate negatives; (3) for collection of data on the latent image.

Following the publication by R. Terenin,[3] A. L. Schoen and R. M. Briggs [4] of the Department of Physics of these Laboratories investigated the practical application of the Herschel effect to infra-red photography. Working with various materials, they investigated spectroscopically the application of a suitable red filter for a simplified study of the Herschel effect. It was found that the Wratten No. 87 filter transmitted the most effective wave-lengths for plates treated with malachite green. Filters Nos. 89 and 88 cut too far into the visible spectrum and the radiation which they transmitted did not reverse a plate treated with malachite green but increased the density. Filters Nos. 740 and 724 produced a much weaker reversal than the No. 87 filter, indicating that they, also, cut too far into the red. From this it appears that the maximum reversal for the plate treated with malachite

[2] "Grundlagen der photographischen Negativverfahren," Eder's Handbuch, **2**: 1927; "The Herschel Effect as a Regression Phenomenon," Seventh International Congress of Photography, London, 1928.

[3] *Z. Physik*, **23**: 294 (1924).

[4] "Infra-red Photography by Means of the Herschel Effect, Report No. 2484/3a.

green is between 725 and 850 $m\mu$; beyond 850 $m\mu$ reversal becomes rapidly weaker, until at 1000 $m\mu$ very little reversal is obtained.

In their investigations A. L. Schoen and R. M. Briggs succeeded in producing results which were much better than those produced in the infra-red with plates bathed in dicyanine. Nevertheless, this work was discontinued after the discovery in these Laboratories of several very powerful optical sensitizers for the extreme red and the infra-red, which gave much better results than those obtained previously in the infra-red. The investigations showed that the best results for a Herschel effect were obtainable with filter No. 87. Preliminary experiments showed that to obtain a pronounced Herschel effect the intensity of the long wave-length exposure is of the greatest importance. Photographic films and plates, which often showed no trace of a Herschel effect in the spectrograph, showed this effect immediately upon increasing the intensity of the light source. Lüppo-Cramer [5] mentions: "Draper was aware of the importance of the intensity of the light in its bleaching action." It is clear that we have to deal with the failure of the reciprocity law. It is much easier to get high intensities of radiation with a light source and a filter, than with a spectroscope, as long as strictly monochromatic light is not required.

### THE SIGNIFICANCE OF THE HERSCHEL EFFECT FOR THE LATENT IMAGE.

To some extent one is able to draw a parallel between the light action on photographic plates and certain chemical reactions. A well known example is the action of hydrogen peroxide on highly sensitive plates. The curves obtained are of the same shape as those obtained with blue light exposure.[6]

Dombrowsky and Lüppo-Cramer were able to obtain reversal with excess of hydrogen peroxide, just as solarization is obtained with overexposure. The latent image can be

[5] *Loc. cit.*

[6] Dombrowsky, Leipzig, 1911 (*Dissertation*). Lüppo-Cramer, *Z. wiss. Phot.*, **25**: 121 (1928); **25**: 129 (1928). *Phot. Korr.*, **64**: 49 (1928). S. E. Sheppard and E. P. Wightman, J. FRANK. INST., **195**: 337 (1923). E. P. Wightman and R. F. Quirk, J. FRANK. INST., **199**: 261, 731 (1927). E. P. Wightman, *J. Amer. Chem. Soc.*, **50**: 2923 (1928). E. P. Wightman and R. F. Quirk (to be published in *Proc. Seventh International Congress of Phot.*, Abstract in *Brit. J. Phot.*, **75**: 420 (1928).

intensified with small amounts of hydrogen peroxide or, as shown by M. L. Dundon, by means of a short after-exposure. Of all the substances which have, from time to time, been examined because of their activity on the photographic plate, hydrogen peroxide has shown itself the most suitable for quantitative investigation. Allylthiourea in a developer causes the plate to fog. If allylthiourea is added to a slow developer during the process of development, a reversal occurs which corresponds to the Sabatier reversal,[7] produced by active light falling upon an exposed photographic plate during the process of slow development. In all probability, therefore, the Waterhouse reversal [8] belongs to the same class of phenomena as the Sabatier reversal; the light action is replaced only by an equivalent chemical fogging action. If this is true, the sulfite reversal [9] by sulfite fog belongs in this same class of reversal phenomena.

Investigators of about 30 years ago wrote of the possibility of increasing the sensitivity of a photographic plate by pre-exposure. J. M. Eder [10] states that by exposing a silver bromide emulsion for 2 minutes to the red light of his dark-room lamp, he was able to increase the threshold speed from 15°–19° Warnerke; 6 minutes' pre-exposure gave an increase of 19°–20° Warnerke. Longer pre-exposure produced fog. Similar experiments were published by J. Gaedicke.[11] Experiments of recent date show very little or no increase of sensitivity by pre-exposure of photographic emulsions. During the last 30 years the limits of sensitivity of various photographic emulsions have been approached.

A parallel effect was noticed by sensitizing silver halide with silver sulfide. S. E. Sheppard [12] discovered that allylthiourea in slightly alkaline gelatin solutions forms small specks of silver sulfide on silver halide crystals. These specks sensitize the silver halide very powerfully. After this discovery of Sheppard, other investigators tried to sensitize with allylthiourea already highly sensitive photographic

[7] Eder's Handbuch, **2**: 82 (1898).
[8] *Brit. J. Phot.*, **37**: 601 and 613 (1890).
[9] C. E. K. Mees and C. W. Piper: *Brit. J. Phot.*, **58**: 491 (1911).
[10] Eder's Handbuch, **3**: 85 (1903).
[11] *Eder's Jahrbuch*, 122 (1898).
[12] *Phot. J.*, **65**: 380 (1925).

emulsions and found that the sensitizing effect was very small; in some cases the only effect was fog. Silver sulfide is a sensitizer only for silver halide that has not yet reached its maximum sensitivity. This limit is determined by the appearance of fog. Before a grain in an insensitive photographic emulsion becomes developable it must be affected by an exposure to light. This final exposure to light may be replaced in part by a pre-exposure or by a chemical reaction. This use of pre-exposure or chemical reaction to replace the pre-exposure is known as increasing sensitivity. Too much pre-exposure gives fog. Too much chemical action also gives fog.

Several fogging agents are able to give effects similar to those of silver sulfide, even if they are not of the same degree. Recently B. H. Carroll and D. Hubbard [13] were able to increase the sensitivity of silver halide with colloidal silver and colloidal gold.

On the other hand there are desensitizers which have the same reaction on the latent image as the extreme red radiation. Phenosafranine, well known through Lüppo-Cramer's [14] investigations on desensitizers, reduces, in higher concentrations, just as do Fe'''—and Cu''—salts. These salts are desensitizers of silver halide for ordinary exposure, but at the same time are sensitizers for the Herschel effect.[15]

There are certain dyes, which desensitize and at the same time produce fog. Methylene blue is a well known example. This double action, which seems contradictory, is not exceptional. Sensitizing of silver halide can be produced by various substances. It is possible that methylene blue forms with silver halide a complex compound in the form of developable centers and at the same time desensitizes already existing sensitivity centers of another chemical nature. Fog centers and sensitivity centers are not always of the same chemical composition. The most important fact regarding desensitization, however, is the discovery of S. E. Sheppard and E. P. Wightman [16] that potassium bromide is a desensitizer. This

[13] *Research Paper No. 20, Bur. of Standards J. Research*, 1: Oct., 1928.

[14] *Negativ entwicklung bei hellem Lichte.*

[15] B. H. Carroll, *J. Phys. Chem.*, 29: 693 (1925).

[16] "Effect of Environment on Photographic Sensitivity: II. Effect of Certain Salts on Sensitivity, *Phot. J.*, 69: 134 (1929).

was to be expected, since H. Arens [17] had already shown that potassium bromide is a sensitizer for the Herschel effect. By carefully washing with distilled water all of the potassium bromide from a photographic emulsion, the Herschel effect disappeared. Arens concludes that the Herschel effect is a desensitizing effect of potassium bromide in red light. As a matter of fact the Herschel effect is not a desensitizing phenomenon; it is a real destruction of the developability of the latent image already formed by some other exposure. Also, it seems better to change Arens' statement that desensitizing is a sensitized Herschel effect to the statement that desensitizers are, in general, sensitizers for the Herschel effect. It seems that the reverse is also true, sensitizers for the latent image are desensitizers for the Herschel effect. Most photographic emulsions contain more or less small amounts of free potassium bromide. Since little is known of desensitizers, an investigation of the Herschel effect is of importance in their study. Until now the quantitative study of the Herschel effect has been made on a limited scale. The purpose of this investigation is to extend this quantitative study and obtain more information relating to the action of desensitizers.

### PHOTOGRAPHIC MATERIAL AND DEVELOPERS.

Preliminary investigations with various kinds of photographic emulsions showed that pure silver bromide emulsion gives a more pronounced Herschel effect than a silver bromoiodide emulsion. The silver bromide was precipitated using potassium bromide of which the iodide content was less than 0.002 per cent. The free potassium bromide content of the coated plates was found by A. E. Ballard of the Department of Analytical Chemistry of these Laboratories to be about 0.03 per cent. of the amount of silver bromide. The emulsion has a wide range of grain sizes as is shown by the size-frequency curves and photomicrographs in Fig. 1. For 4 minutes' development with pyro-soda at 68° F. (exposure made to acetylene light, screened to daylight with No. 79 Wratten filter) the sensitometric test showed a speed of 63 H. and D.; gamma, 1.12; with fog, 0.07. To investigate the Herschel

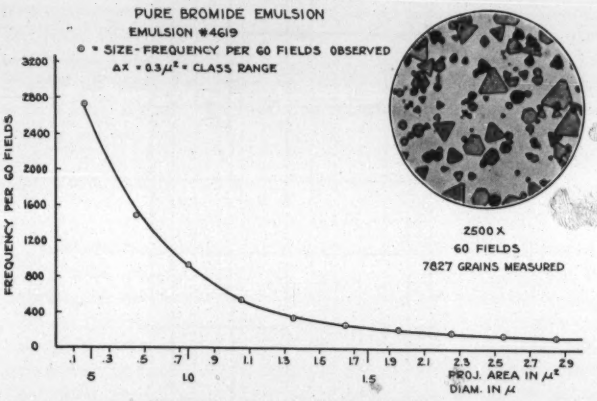
[17] *Z. physik. Chem.*, 114: 379 (1925).

effect, development was effected at 17° C., controlled by a thermostat, with brush [18] in pyro-soda:

| | | |
|---|---|---|
| Pyro (M/20) | 6.304 | grams |
| Sodium sulfite, anhydrous | 25 | " |
| Sodium carbonate | 21.2 | " |
| Potassium bromide (M/100) | 1.19 | " |
| Water to make | 1 | liter |

The sulfur dioxide content of the sodium sulfite used was determined and the actual amount calculated for an equiva-

FIG. 1.




lent of 100 per cent. pure salt. Development was stopped at the required time with dilute acetic acid (1%); the plate was fixed in an acid fixing bath. Densities were read on a Jones' densitometer.[19]

### THE SENSITOMETER.

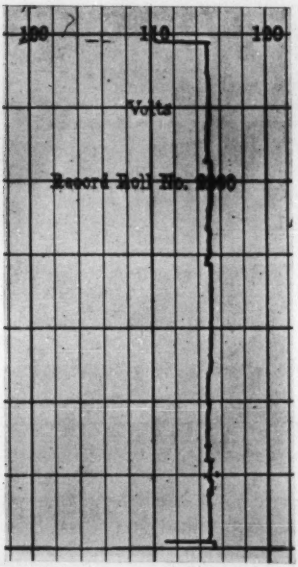
The exposures were made with a non-intermittent sensitometer of 26 steps of $\sqrt{2}$ ratio. The light intensity was kept constant while the time of exposure was varied; the maximum time of exposure was 579 seconds. The light source was a 500-candle power standard monoplane tungsten filament lamp operated at 104.8 volts, with a color temperature of 2700° K.

[18] *Cf.* W. Clark, *Phot. J.*, **65**: 76 (1925).

[19] *J. Opt. Soc. Amer.*, **7**: 230 (1923).

On account of the many and long exposures it was necessary to keep the light intensity as constant as possible. For this purpose a voltage regulator which maintained voltage constant to within one volt, was built by A. L. Schoen. A record is shown in Fig. 2 in which vertical lines represent

FIG. 2.




time, and every step, 10 minutes. The horizontal lines represent potential differences; the distance between two vertical lines representing 2 volts. Several tests were made. The deviations in potential correspond with less than 6 per cent. intensity difference in the blue light and with less than 3 per cent. intensity difference in the extreme red.

Both exposures were given without any change of the light source at one-meter distance from the photographic plate;

only the filter, the diaphragm, and the diffusion screen between light source and photographic plate were changed. The changes are given in the following table:

| Exposure | Blue Light | Infra-red radiation |
|---|---|---|
| Filter | No. 49 | No. 87 |
| Total transmission | 0.5 per cent. | Not determined |
| Wave-length transmission | 505–535 $m\mu$ | Beyond 700 $m\mu$ |
| Diffusion medium | Opal glass | Ground glass |
| Diaphragm (diffusing media and diaphragm) | 1.119 c.p. | 444.66 c.p. |

The blue filter transmits some infra-red light. Even when this transmission is of the same order as that of filter No. 87, the total intensity on the photographic plate would be 400 times less than with the infra-red radiation exposure. To absorb all infra-red radiation, filter No. 49 was combined with a cell, 2.5 cm. thick, containing a 5 per cent. solution of copper sulfate in water. No difference was noticeable when filter No. 49 was used alone or with the copper sulfate cell. Therefore, this effect can be neglected.

### EXPOSURE AND DEVELOPMENT.

J. Plotnikow [20] suggested an investigation of the Herschel effect with cross exposures. In this way it is possible to investigate the Herschel effect with constant infra-red radiation on different blue light exposures, and different infra-red radiations on a constant blue light exposure.[21] The blue light exposure was made in 26 steps and the infra-red light exposure was then made perpendicularly upon it, also in 26 steps. Only a part of these exposed areas appeared in the developer. From the blue light exposure only 22 steps, and from the infra-red radiation only 12 steps were readable. Until now no investigations have been published on the action of the Herschel effect with time of development, so that many data had to be collected to determine the density-time of development curves. The plates were developed for 2, 3, 4, 5, 6, 7, 8, 10, 12, 16, 22, and 32 minutes. The same procedure was repeated 5 times, so that 60 plates were exposed and developed, each containing 22 by 12 densities. Not all these densities

[20] "Photochemie," 650 (1920).

[21] *Cf.* Lüppo-Cramer, "Die Grundlagen der photographischen Negativverfahren," 716 (1927).

were read but only as many as were needed for obtaining the required results.

### TREATMENT OF DATA.

The results of averaging five sensitometric data are not sufficient for the determination of the final data. Compared with the development errors, the errors in exposure and density reading are negligible. Five sensitometric determinations are sufficiently reliable to determine the shape of the curve. The gamma of the curve for time of development was corrected by a method of smoothing suggested by L. A. Jones. Values from the H. and D. curves were plotted as functions of development time; the smoothed values from the density-time errors were then replotted as H. and D. curves. This may be repeated. The results obtained show that up to about 10 minutes' development, the curves are very reliable and represent the real data as nearly as it is possible under these circumstances to determine them. Beyond 10 minutes' development, differences in thickness of the emulsion influence the densities so greatly that the deviations in densities increase and the averaging becomes less accurate. No fog correction was applied to the data.

### DISCUSSION OF THE DATA.

In Fig. 3 are given the H. and D. curves and in Fig. 4 are given the density-time of development curves for blue light exposures alone. For these and the next group of curves the density measurements have been carefully extended from 22 to 25 steps, but they were not drawn in the sets of H. and D. curves. Step 25 represents the increase of fog with time of development. In all cases the strongest exposure was represented by step 1.

In Fig. 5 are given the H. and D. curves and in Fig. 6 the density-time of development curves for blue light exposures, which have received an additional infra-red exposure for 579 seconds ($\log E_r = 3.60$), the maximum infra-red exposure given in this series of experiments. In Fig. 6, step 25 represents the increase of density with time of development for infra-red exposure alone.

FIG. 3.

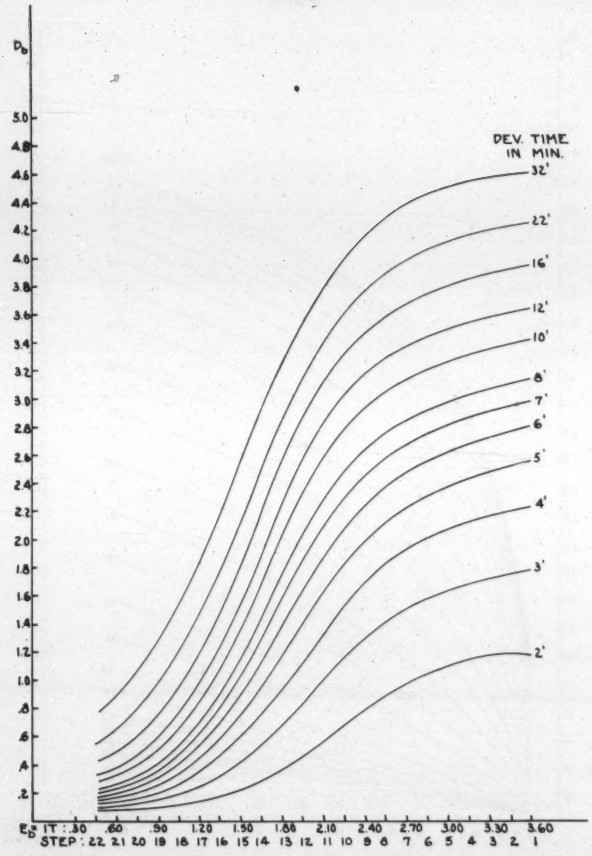

$D_b$
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
$E_b$
DEV. TIME IN MIN.
32'
22'
16'
12'
10'
8'
7'
6'
5'
4'
3'
2'
I.T. : .30 .60 .90 1.20 1.50 1.80 2.10 2.40 2.70 3.00 3.30 3.60
STEP : 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

FIG. 4.

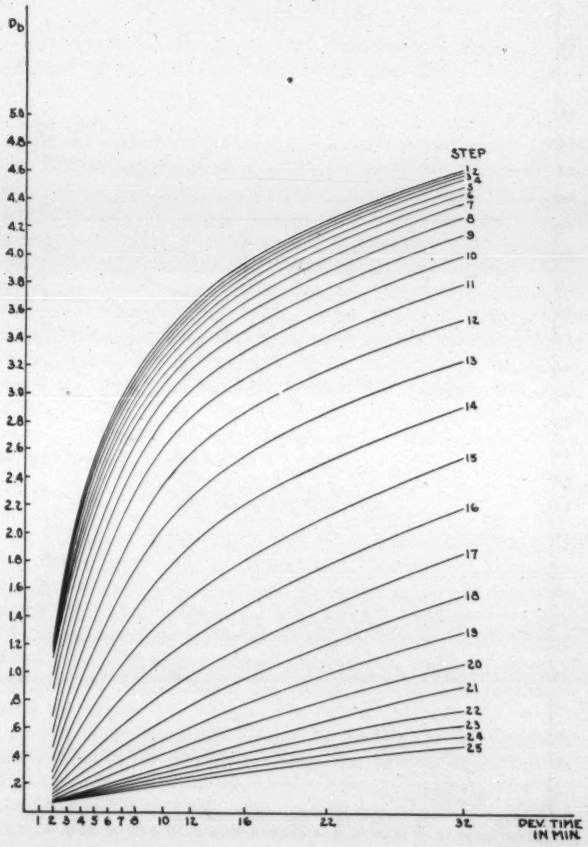

$D_D$
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
STEP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
1 2 3 4 5 6 7 8 10 12 16 22 32
DEV. TIME IN MIN.

FIG. 5.

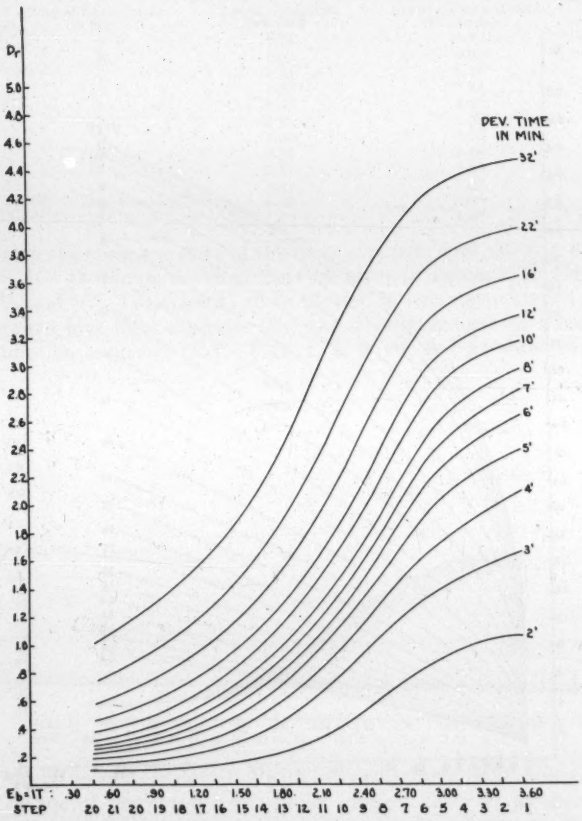
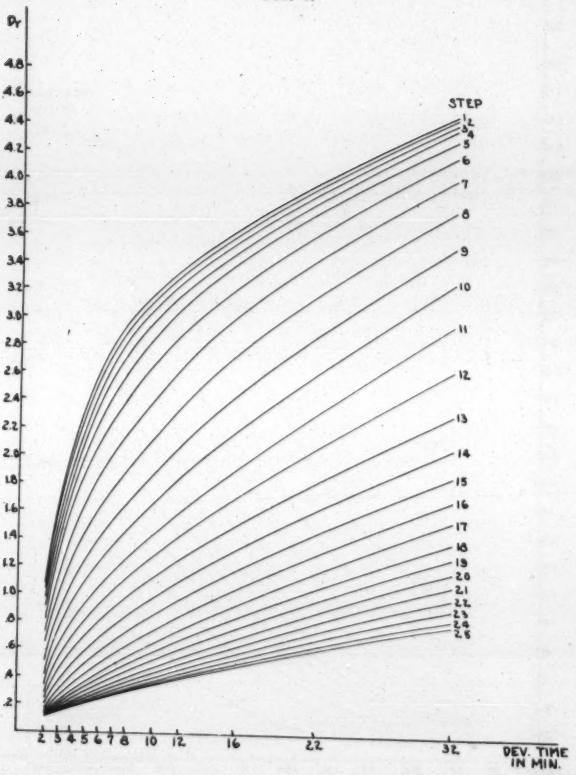

$D_r$
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
DEV. TIME IN MIN.
32'
22'
16'
12'
10'
8'
7'
6'
5'
4'
3'
2'
$E_b$=IT : .30 .60 .90 1.20 1.50 1.80 2.10 2.40 2.70 3.00 3.30 3.60
STEP 20 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

FIG. 6.

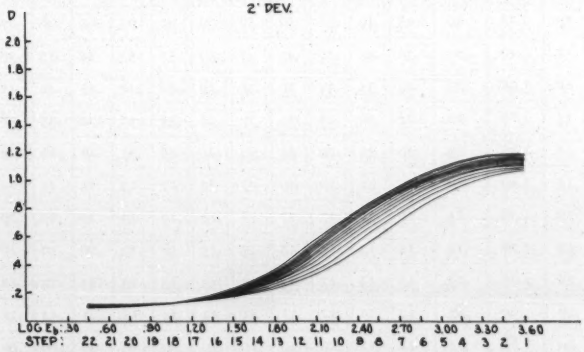

Dr
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
STEP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
2 3 4 5 6 7 8 10 12 16 22 32
DEV. TIME IN MIN.

In comparing these curves, it is noticeable that their shapes change with a change in gamma:

| Time of Development in Min. | Gamma (Blue Light Exposure) | Gamma (Blue and Infra-red Exposure) |
|---|---|---|
| 2 | 0.72 | 0.70 |
| 3 | 1.07 | 0.97 |
| 4 | 1.36 | 1.18 |
| 5 | 1.58 | 1.34 |
| 6 | 1.76 | 1.47 |
| 7 | 1.91 | 1.58 |
| 8 | 2.02 | 1.66 |
| 10 | 2.19 | 1.75 |
| 12 | 2.29 | 1.82 |
| 16 | 2.40 | 1.91 |
| 22 | 2.49 | 1.98 |
| 32 | 2.52 | 2.00 |

From the complete data of the cross exposure only the 2, 4, 8, 16, and 32-minute developments are given in Tables I, II, III, IV, and V. These data can be plotted in two ways: Density against blue light exposure ($E_b$) and density against infra-red radiation exposure ($E_r$). Figs. 7, 8, 9, 10, and 11 show the

FIG. 7.




gradual decrease in densities with increasing infra-red exposure. The toe of the curve is of special interest since we see here that the infra-red exposure is too strong, in relation to the weak blue light exposures, to show any Herschel effect. The density increases with the secondary infra-red exposure, but always to a less degree until a certain neutral point is reached, after which the Herschel effect appears.

TABLE I.

2 MINUTES DEVELOPMENT.

| Step | Infra-red → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blue ↓ | Log $E$ | 3.60 | 3.45 | 3.30 | 3.15 | 3.00 | 2.85 | 2.70 | 2.55 | 2.40 | 2.25 | 2.10 | 1.95 |
| 1 | 3.60 | 1.06 | 1.08 | 1.10 | 1.11 | 1.12 | 1.13 | 1.14 | 1.15 | 1.16 | 1.17 | 1.18 | 1.18 |
| 2 | 3.45 | 1.05 | 1.07 | 1.09 | 1.10 | 1.11 | 1.12 | 1.13 | 1.14 | 1.15 | 1.16 | 1.17 | 1.17 |
| 3 | 3.30 | 1.01 | 1.03 | 1.06 | 1.08 | 1.09 | 1.11 | 1.12 | 1.13 | 1.14 | 1.15 | 1.16 | 1.16 |
| 4 | 3.15 | .96 | .99 | 1.02 | 1.04 | 1.06 | 1.08 | 1.10 | 1.11 | 1.12 | 1.13 | 1.14 | 1.14 |
| 5 | 3.00 | .89 | .92 | .96 | .98 | 1.01 | 1.03 | 1.04 | 1.06 | 1.07 | 1.08 | 1.09 | 1.10 |
| 6 | 2.85 | .80 | .84 | .88 | .91 | .94 | .96 | .98 | 1.00 | 1.01 | 1.02 | 1.03 | 1.04 |
| 7 | 2.70 | .71 | .76 | .80 | .83 | .86 | .88 | .90 | .92 | .93 | .94 | .95 | .96 |
| 8 | 2.55 | .60 | .65 | .70 | .73 | .76 | .79 | .81 | .83 | .84 | .85 | .86 | .87 |
| 9 | 2.40 | .50 | .56 | .60 | .64 | .67 | .70 | .72 | .74 | .75 | .76 | .77 | .78 |
| 10 | 2.25 | .40 | .45 | .49 | .52 | .56 | .58 | .60 | .62 | .63 | .64 | .66 | .67 |
| 11 | 2.10 | .32 | .36 | .40 | .42 | .45 | .47 | .49 | .51 | .52 | .54 | .55 | .56 |
| 12 | 1.95 | .27 | .29 | .32 | .34 | .36 | .38 | .40 | .41 | .42 | .43 | .44 | .45 |
| 13 | 1.80 | .22 | .24 | .26 | .28 | .29 | .30 | .31 | .32 | .33 | .34 | .35 | .36 |
| 14 | 1.65 | .19 | .20 | .21 | .22 | .23 | .24 | .25 | .26 | .27 | .28 | .29 | .29 |
| 15 | 1.50 | .17 | .17 | .18 | .19 | .20 | .21 | .22 | .22 | .23 | .23 | .24 | .24 |
| 16 | 1.35 | .15 | .16 | .16 | .17 | .17 | .18 | .18 | .19 | .19 | .20 | .20 | .20 |
| 17 | 1.20 | .14 | .14 | .14 | .15 | .15 | .15 | .15 | .16 | .16 | .16 | .16 | .16 |
| 18 | 1.05 | .13 | .13 | .13 | .13 | .13 | .13 | .13 | .13 | .13 | .13 | .13 | .13 |
| 19 | .90 | .12 | .12 | .12 | .12 | .11 | .11 | .11 | .11 | .11 | .11 | .11 | .11 |
| 20 | .75 | .11 | .11 | .11 | .10 | .10 | .10 | .10 | .09 | .09 | .09 | .09 | .09 |
| 21 | .60 | .10 | .10 | .10 | .09 | .09 | .09 | .09 | .08 | .08 | .08 | .08 | .08 |
| 22 | .45 | .10 | .10 | .09 | .09 | .09 | .08 | .08 | .08 | .07 | .07 | .07 | .07 |

TABLE II.

4 MINUTES DEVELOPMENT.

| Step | Infra-red → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blue ↓ | Log $E$ | 3.60 | 3.45 | 3.30 | 3.15 | 3.00 | 2.85 | 2.70 | 2.55 | 2.40 | 2.25 | 2.10 | 1.95 |
| 1 | 3.60 | 2.09 | 2.11 | 2.12 | 2.14 | 2.16 | 2.17 | 2.18 | 2.19 | 2.20 | 2.21 | 2.22 | 2.22 |
| 2 | 3.45 | 2.01 | 2.04 | 2.07 | 2.09 | 2.11 | 2.13 | 2.14 | 2.16 | 2.17 | 2.18 | 2.19 | 2.20 |
| 3 | 3.30 | 1.92 | 1.97 | 2.01 | 2.04 | 2.06 | 2.08 | 2.10 | 2.12 | 2.14 | 2.15 | 2.16 | 2.16 |
| 4 | 3.15 | 1.83 | 1.89 | 1.94 | 1.98 | 2.01 | 2.04 | 2.06 | 2.08 | 2.10 | 2.11 | 2.12 | 2.12 |
| 5 | 3.00 | 1.72 | 1.80 | 1.86 | 1.91 | 1.95 | 1.98 | 2.00 | 2.02 | 2.04 | 2.05 | 2.06 | 2.07 |
| 6 | 2.85 | 1.59 | 1.69 | 1.76 | 1.81 | 1.86 | 1.90 | 1.93 | 1.96 | 1.98 | 1.99 | 2.00 | 2.01 |
| 7 | 2.70 | 1.44 | 1,56 | 1.65 | 1.71 | 1.76 | 1.80 | 1.84 | 1.86 | 1.89 | 1.91 | 1.92 | 1.93 |
| 8 | 2.55 | 1.27 | 1.40 | 1.50 | 1.57 | 1.62 | 1.67 | 1.71 | 1.74 | 1.76 | 1.78 | 1.80 | 1.82 |
| 9 | 2.40 | 1.10 | 1.23 | 1.32 | 1.40 | 1.46 | 1.50 | 1.55 | 1.59 | 1.62 | 1.64 | 1.66 | 1.68 |
| 10 | 2.25 | .95 | 1.06 | 1.15 | 1.21 | 1.27 | 1.32 | 1.36 | 1.40 | 1.43 | 1.46 | 1.49 | 1.51 |
| 11 | 2.10 | .80 | .91 | .98 | 1.04 | 1.10 | 1.14 | 1.18 | 1.21 | 1.24 | 1.27 | 1.29 | 1.31 |
| 12 | 1.95 | .68 | .76 | .82 | .87 | .92 | .96 | .99 | 1.02 | 1.04 | 1.06 | 1.09 | 1.11 |
| 13 | 1.80 | .57 | .63 | .68 | .72 | .76 | .80 | .82 | .85 | .87 | .89 | .91 | .93 |
| 14 | 1.65 | .47 | .52 | .56 | .60 | .63 | .65 | .68 | .70 | .72 | .73 | .75 | .76 |
| 15 | 1.50 | .40 | .43 | .47 | .50 | .52 | .54 | .55 | .57 | .58 | .59 | .60 | .60 |
| 16 | 1.35 | .33 | .35 | .37 | .39 | .40 | .42 | .43 | .44 | .44 | .45 | .46 | .46 |
| 17 | 1.20 | .28 | .29 | .30 | .31 | .32 | .33 | .33 | .34 | .34 | .34 | .34 | .34 |
| 18 | 1.05 | .24 | .24 | .25 | .25 | .25 | .26 | .26 | .26 | .26 | .26 | .26 | .26 |
| 19 | .90 | .22 | .21 | .21 | .21 | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 |
| 20 | .75 | .20 | .19 | .19 | .18 | .18 | .17 | .17 | .16 | .16 | .16 | .16 | .16 |
| 21 | .60 | .19 | .18 | .17 | .16 | .16 | .15 | .15 | .14 | .14 | .13 | .13 | .13 |
| 22 | .45 | .18 | .17 | .16 | .15 | .14 | .13 | .13 | .12 | .12 | .11 | .11 | .11 |

## TABLE III.

### 8 MINUTES DEVELOPMENT.

| Step | Infra-red → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blue ↓ | Log $E$ | 3.60 | 3.45 | 3.30 | 3.15 | 3.00 | 2.85 | 2.70 | 2.55 | 2.40 | 2.25 | 2.10 | 1.95 |
| 1 | 3.60 | 2.96 | 2.99 | 3.02 | 3.04 | 3.06 | 3.07 | 3.09 | 3.10 | 3.11 | 3.12 | 3.12 | 3.13 |
| 2 | 3.45 | 2.90 | 2.93 | 2.96 | 2.99 | 3.02 | 3.03 | 3.05 | 3.06 | 3.08 | 3.09 | 3.10 | 3.10 |
| 3 | 3.30 | 2.82 | 2.86 | 2.90 | 2.93 | 2.96 | 2.98 | 3.00 | 3.02 | 3.03 | 3.04 | 3.05 | 3.06 |
| 4 | 3.15 | 2.72 | 2.78 | 2.82 | 2.86 | 2.90 | 2.93 | 2.95 | 2.97 | 2.99 | 3.00 | 3.01 | 3.02 |
| 5 | 3.00 | 2.57 | 2.65 | 2.72 | 2.76 | 2.81 | 2.84 | 2.88 | 2.90 | 2.92 | 2.94 | 2.96 | 2.97 |
| 6 | 2.85 | 2.39 | 2.50 | 2.59 | 2.65 | 2.70 | 2.75 | 2.79 | 2.82 | 2.84 | 2.87 | 2.89 | 2.91 |
| 7 | 2.70 | 2.14 | 2.31 | 2.42 | 2.51 | 2.58 | 2.63 | 2.68 | 2.72 | 2.76 | 2.79 | 2.82 | 2.84 |
| 8 | 2.55 | 1.89 | 2.10 | 2.24 | 2.35 | 2.44 | 2.51 | 2.58 | 2.63 | 2.67 | 2.70 | 2.73 | 2.75 |
| 9 | 2.40 | 1.66 | 1.90 | 2.06 | 2.18 | 2.28 | 2.38 | 2.45 | 2.51 | 2.55 | 2.58 | 2.61 | 2.63 |
| 10 | 2.25 | 1.45 | 1.65 | 1.80 | 1.94 | 2.05 | 2.16 | 2.25 | 2.32 | 2.38 | 2.42 | 2.46 | 2.48 |
| 11 | 2.10 | 1.26 | 1.41 | 1.55 | 1.66 | 1.78 | 1.88 | 1.97 | 2.05 | 2.12 | 2.19 | 2.22 | 2.27 |
| 12 | 1.95 | 1.10 | 1.21 | 1.33 | 1.42 | 1.52 | 1.61 | 1.70 | 1.78 | 1.86 | 1.93 | 1.98 | 2.02 |
| 13 | 1.80 | .95 | 1.04 | 1.13 | 1.22 | 1.30 | 1.38 | 1.45 | 1.52 | 1.58 | 1.64 | 1.69 | 1.73 |
| 14 | 1.65 | .82 | .89 | .96 | 1.02 | 1.08 | 1.15 | 1.20 | 1.26 | 1.31 | 1.36 | 1.40 | 1.44 |
| 15 | 1.50 | .71 | .76 | .80 | .85 | .90 | .94 | .98 | 1.02 | 1.06 | 1.09 | 1.12 | 1.15 |
| 16 | 1.35 | .61 | .64 | .67 | .70 | .74 | .76 | .79 | .82 | .84 | .86 | .88 | .90 |
| 17 | 1.20 | .54 | .56 | .58 | .60 | .61 | .63 | .74 | .76 | .77 | .78 | .79 | .80 |
| 18 | 1.05 | .48 | .48 | .49 | .50 | .50 | .51 | .52 | .52 | .53 | .54 | .54 | .54 |
| 19 | .90 | .42 | .42 | .42 | .42 | .42 | .42 | .42 | .42 | .42 | .42 | .42 | .42 |
| 20 | .75 | .38 | .37 | .36 | .35 | .34 | .34 | .34 | .33 | .33 | .33 | .32 | .32 |
| 21 | .60 | .34 | .33 | .32 | .31 | .30 | .29 | .28 | .28 | .27 | .27 | .26 | .26 |
| 22 | .45 | .32 | .30 | .29 | .28 | .27 | .26 | .25 | .24 | .23 | .23 | .22 | .22 |

TABLE IV.

16 MINUTES DEVELOPMENT.

| Step | Infra-red → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blue ↓ | Log $E$ | 3.60 | 3.45 | 3.30 | 3.15 | 3.00 | 2.85 | 2.70 | 2.55 | 2.40 | 2.25 | 2.10 | 1.95 |
| 1 | 3.60 | 3.62 | 3.67 | 3.72 | 3.76 | 3.79 | 3.82 | 3.85 | 3.87 | 3.89 | 3.91 | 3.93 | 3.94 |
| 2 | 3.45 | 3.59 | 3.64 | 3.69 | 3.73 | 3.76 | 3.80 | 3.82 | 3.85 | 3.87 | 3.89 | 3.90 | 3.91 |
| 3 | 3.30 | 3.54 | 3.60 | 3.65 | 3.70 | 3.73 | 3.76 | 3.79 | 3.81 | 3.83 | 3.85 | 3.87 | 3.88 |
| 4 | 3.15 | 3.47 | 3.53 | 3.59 | 3.64 | 3.68 | 3.71 | 3.74 | 3.77 | 3.79 | 3.81 | 3.83 | 3.84 |
| 5 | 3.00 | 3.37 | 3.45 | 3.51 | 3.57 | 3.61 | 3.65 | 3.68 | 3.71 | 3.74 | 3.76 | 3.78 | 3.80 |
| 6 | 2.85 | 3.22 | 3.32 | 3.40 | 3.46 | 3.51 | 3.56 | 3.59 | 3.63 | 3.66 | 3.69 | 3.72 | 3.74 |
| 7 | 2.70 | 3.00 | 3.14 | 3.24 | 3.33 | 3.39 | 3.44 | 3.50 | 3.53 | 3.57 | 3.60 | 3.63 | 3.66 |
| 8 | 2.55 | 2.73 | 2.92 | 3.06 | 3.17 | 3.25 | 3.32 | 3.39 | 3.44 | 3.48 | 3.52 | 3.54 | 3.57 |
| 9 | 2.40 | 2.42 | 2.62 | 2.80 | 2.96 | 3.08 | 3.18 | 3.26 | 3.32 | 3.36 | 3.40 | 3.42 | 3.45 |
| 10 | 2.25 | 2.16 | 2.36 | 2.54 | 2.69 | 2.84 | 2.96 | 3.05 | 3.14 | 3.20 | 3.24 | 3.28 | 3.30 |
| 11 | 2.10 | 1.91 | 2.10 | 2.28 | 2.44 | 2.59 | 2.72 | 2.83 | 2.92 | 2.99 | 3.04 | 3.08 | 3.10 |
| 12 | 1.95 | 1.68 | 1.83 | 1.98 | 2.12 | 2.24 | 2.38 | 2.49 | 2.60 | 2.68 | 2.76 | 2.81 | 2.84 |
| 13 | 1.80 | 1.50 | 1.63 | 1.76 | 1.87 | 1.98 | 2.09 | 2.19 | 2.28 | 2.36 | 2.43 | 2.50 | 2.54 |
| 14 | 1.65 | 1.32 | 1.42 | 1.52 | 1.61 | 1.71 | 1.80 | 1.88 | 1.95 | 2.02 | 2.09 | 2.15 | 2.20 |
| 15 | 1.50 | 1.17 | 1.24 | 1.31 | 1.38 | 1.44 | 1.51 | 1.57 | 1.62 | 1.67 | 1.72 | 1.77 | 1.81 |
| 16 | 1.35 | 1.04 | 1.08 | 1.13 | 1.17 | 1.22 | 1.26 | 1.30 | 1.34 | 1.38 | 1.41 | 1.44 | 1.47 |
| 17 | 1.20 | .94 | .96 | .99 | 1.02 | 1.04 | 1.07 | 1.09 | 1.11 | 1.13 | 1.15 | 1.17 | 1.19 |
| 18 | 1.05 | .84 | .85 | .86 | .88 | .89 | .90 | .92 | .93 | .94 | .95 | .96 | .96 |
| 19 | .90 | .76 | .76 | .76 | .76 | .76 | .76 | .76 | .76 | .76 | .76 | .76 | .76 |
| 20 | .75 | .68 | .67 | .66 | .65 | .64 | .63 | .62 | .62 | .62 | .61 | .61 | .61 |
| 21 | .60 | .61 | .59 | .58 | .56 | .55 | .54 | .53 | .52 | .52 | .51 | .51 | .50 |
| 22 | .45 | .56 | .54 | .51 | .49 | .48 | .46 | .45 | .44 | .43 | .42 | .42 | .41 |

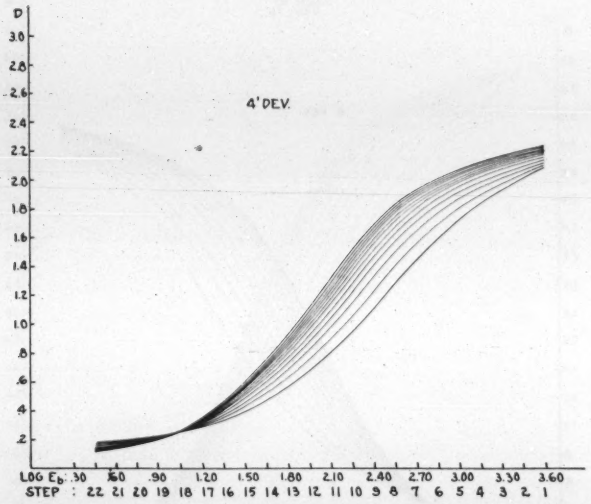
## TABLE V.

### 32 MINUTES DEVELOPMENT.

| Step | Infra-red → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blue ↓ | Log $E$ | 3.60 | 3.45 | 3.30 | 3.15 | 3.00 | 2.85 | 2.70 | 2.55 | 2.40 | 2.25 | 2.10 | 1.95 |
| 1 | 3.60 | 4.46 | 4.49 | 4.51 | 4.53 | 4.55 | 4.56 | 4.57 | 4.58 | 4.59 | 4.59 | 4.60 | 4.60 |
| 2 | 3.45 | 4.44 | 4.47 | 4.49 | 4.51 | 4.53 | 4.54 | 4.55 | 4.56 | 4.57 | 4.57 | 4.58 | 4.58 |
| 3 | 3.30 | 4.40 | 4.43 | 4.45 | 4.47 | 4.49 | 4.50 | 4.51 | 4.52 | 4.53 | 4.54 | 4.55 | 4.56 |
| 4 | 3.15 | 4.36 | 4.39 | 4.41 | 4.43 | 4.46 | 4.48 | 4.49 | 4.50 | 4.51 | 4.52 | 4.52 | 4.53 |
| 5 | 3.00 | 4.28 | 4.32 | 4.35 | 4.38 | 4.40 | 4.42 | 4.44 | 4.45 | 4.46 | 4.47 | 4.48 | 4.49 |
| 6 | 2.85 | 4.16 | 4.21 | 4.25 | 4.28 | 4.31 | 4.34 | 4.37 | 4.39 | 4.40 | 4.42 | 4.43 | 4.44 |
| 7 | 2.70 | 3.98 | 4.04 | 4.10 | 4.15 | 4.19 | 4.22 | 4.25 | 4.28 | 4.31 | 4.33 | 4.35 | 4.36 |
| 8 | 2.55 | 3.76 | 3.85 | 3.92 | 3.98 | 4.03 | 4.08 | 4.12 | 4.15 | 4.19 | 4.22 | 4.24 | 4.27 |
| 9 | 2.40 | 3.52 | 3.66 | 3.76 | 3.83 | 3.89 | 3.94 | 3.99 | 4.02 | 4.06 | 4.09 | 4.12 | 4.14 |
| 10 | 2.25 | 3.24 | 3.40 | 3.52 | 3.60 | 3.68 | 3.74 | 3.79 | 3.83 | 3.88 | 3.92 | 3.95 | 3.98 |
| 11 | 2.10 | 2.93 | 3.13 | 3.26 | 3.36 | 3.44 | 3.50 | 3.56 | 3.61 | 3.66 | 3.70 | 3.74 | 3.78 |
| 12 | 1.95 | 2.61 | 2.78 | 2.91 | 3.01 | 3.11 | 3.19 | 3.27 | 3.33 | 3.39 | 3.43 | 3.48 | 3.51 |
| 13 | 1.80 | 2.32 | 2.44 | 2.56 | 2.66 | 2.76 | 2.86 | 2.95 | 3.03 | 3.10 | 3.17 | 3.21 | 3.24 |
| 14 | 1.65 | 2.07 | 2.17 | 2.27 | 2.36 | 2.44 | 2.52 | 2.60 | 2.68 | 2.75 | 2.81 | 2.86 | 2.90 |
| 15 | 1.50 | 1.86 | 1.94 | 2.01 | 2.08 | 2.16 | 2.22 | 2.28 | 2.34 | 2.40 | 2.44 | 2.49 | 2.53 |
| 16 | 1.35 | 1.68 | 1.73 | 1.78 | 1.83 | 1.88 | 1.93 | 1.98 | 2.02 | 2.06 | 2.09 | 2.12 | 2.15 |
| 17 | 1.20 | 1.53 | 1.56 | 1.59 | 1.62 | 1.65 | 1.68 | 1.71 | 1.73 | 1.76 | 1.78 | 1.80 | 1.82 |
| 18 | 1.05 | 1.40 | 1.41 | 1.43 | 1.44 | 1.46 | 1.47 | 1.48 | 1.50 | 1.51 | 1.51 | 1.52 | 1.52 |
| 19 | .90 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 |
| 20 | .75 | 1.18 | 1.16 | 1.15 | 1.14 | 1.12 | 1.11 | 1.10 | 1.09 | 1.08 | 1.08 | 1.07 | 1.07 |
| 21 | .60 | 1.08 | 1.05 | 1.02 | 1.00 | .98 | .96 | .94 | .93 | .91 | .90 | .89 | .88 |
| 22 | .45 | .99 | .95 | .91 | .87 | .85 | .82 | .80 | .79 | .78 | .77 | .76 | .75 |

Figs. 12, 13, 14, 15, and 16 show the influence, on the blue light latent image, of gradually increasing the infra-red exposure. The data are plotted from the lowest infra-red exposure, as log $E_r = 1.95$. These curves show that the infra-red exposure is able to give a number of different curves

FIG. 8.

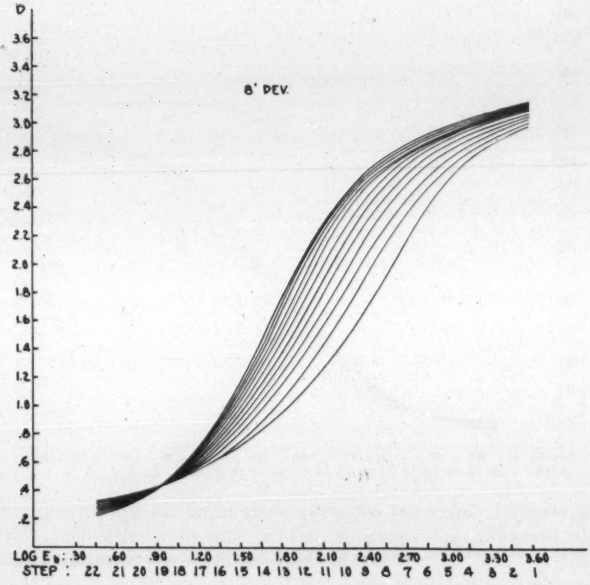



of constant infra-red intensity depending on the amount of the first blue light exposure and the time of development. In spite of the fact that the highest infra-red exposures are unable to form more than the toe of the reversal curve, it is clear that many H. and D. curves varying in form and gamma, are probably possible, if the plates are sensitized with proper sensitizers and more complete Herschel effects are obtained. This makes the sensitized Herschel effect probably suitable for the making of duplicate negatives and direct positives.

If we express the Herschel effect as the difference between the density of the blue light exposure ($D_b$) and the density of the blue light exposure with the additional infra-red exposure

$(D_r)$ thus: $(D_b - D_r)$ we can collect the data in Table VI, where only the data with the strongest infra-red exposure (log $E_r = 3.60$) are taken for the values of $D_r$. Table VI shows that with increasing time of development the neutral point changes from step 18 to step 19. There are two maximum Herschel effects,—one with variable first blue light

FIG. 9.

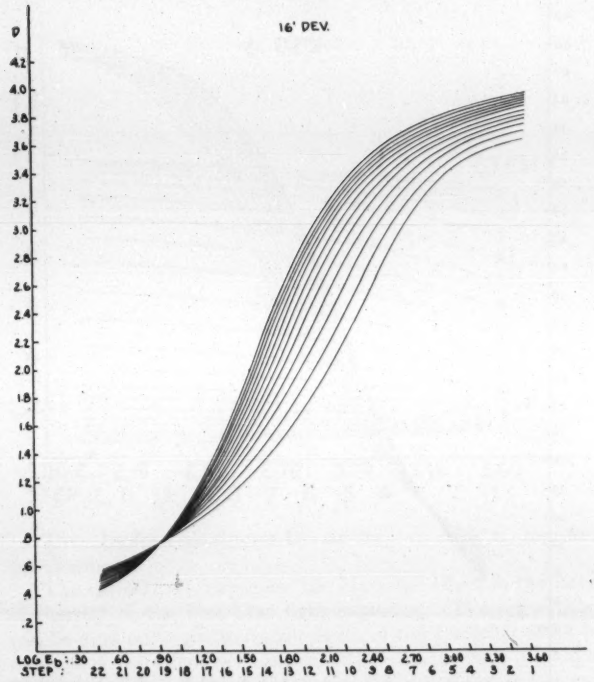



exposure and one with variable time of development. The maximum densities are placed in black squares with all densities $\pm$ 0.03. We see that with development time one maximum moves from step 9 with 2 minutes' development to step 13 with 32 minutes' development. The other maximum moves from 16 minutes' development at step 1 to 10 minutes' development at step 11; and then again back to 22 minutes' and 32 minutes' development at step 18.

The absolute maximum lies at step 11 with 10 minutes' development.

The Herschel effect can also be expressed as the ratio of the two densities $D_r/D_b$. The data for the strongest infra-red

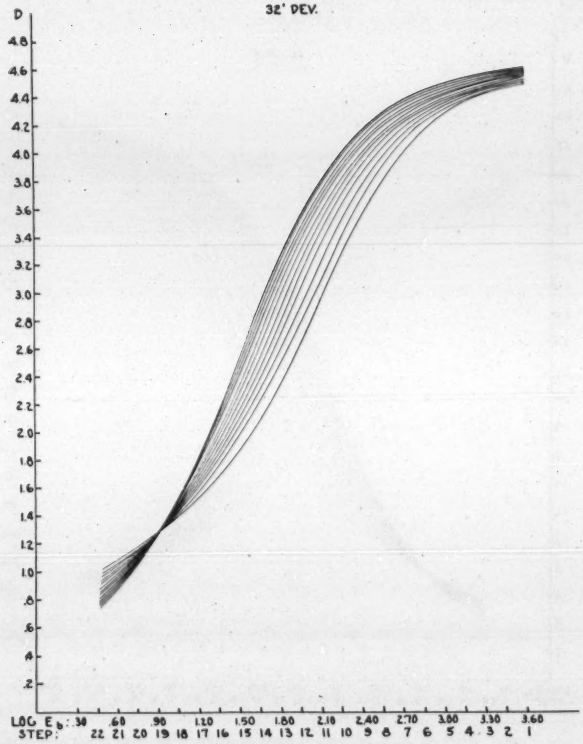
FIG. 10.




exposure, $E_r = 3.60$, are collected in Table VII. The numbers obtained are multiplied by $10^3$. The smaller the number obtained therefore, the greater the Herschel effect. Again, two different maxima appear.

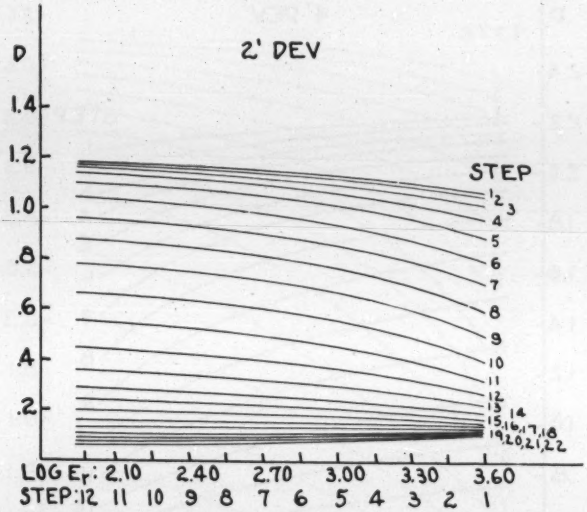
The maximum with different first blue light exposures lies

FIG. 11.


32° DEV.
D
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
LOG E b: .30 .60 .90 1.20 1.50 1.80 2.10 2.40 2.70 3.00 3.30 3.60
STEP: 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

at step 11 with 2 minutes' development and moves to step 14 with 32 minutes' development. The maximum with various times of development moves from step 1–7 with 2 minutes' development to step 18 with 16 minutes' development.

FIG. 12.




The absolute maximum lies at step 12 with 10 minutes' development.

The ratio $D_r/D_b$ expresses the Herschel effect in the unity of density of the first blue light exposure. The same thing can be applied to the first expression of the Herschel effect by expressing the effect per unit of density of the first blue light exposure. We get then

$$\frac{D_b - D_r}{D_b}.$$

Multiplying by $10^2$, we get the well known percentage formula; the data are collected in Table VIII.

FIG. 13.

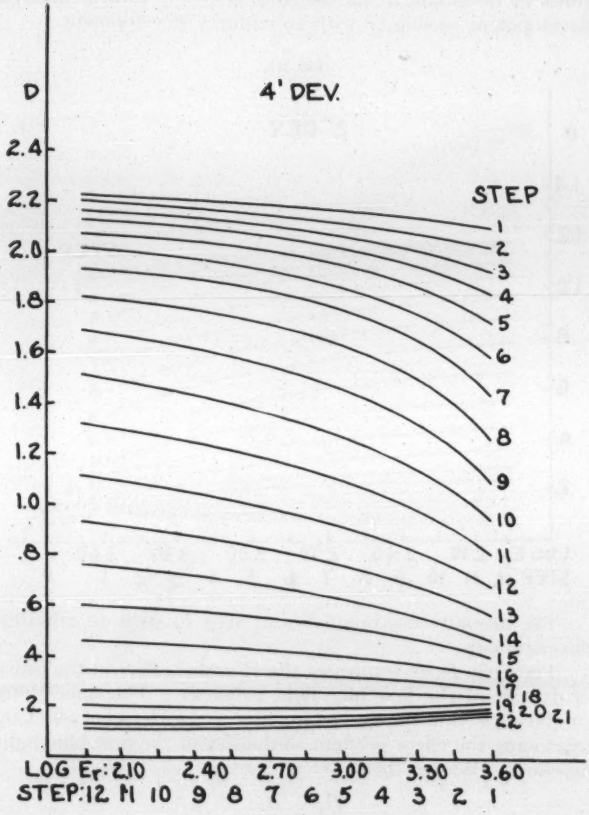

D
4' DEV.
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
STEP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
LOG Ef: 2.10 2.40 2.70 3.00 3.30 3.60
STEP: 12 11 10 9 8 7 6 5 4 3 2 1

FIG. 14.

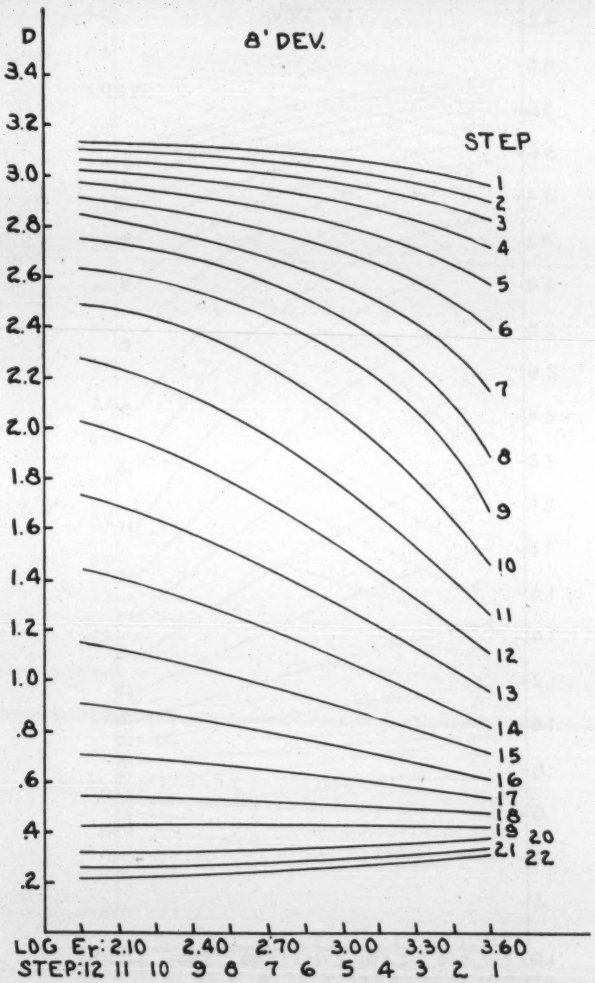

D
S' DEV.
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
STEP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
LOG Er: 2.10 2.40 2.70 3.00 3.30 3.60
STEP: 12 11 10 9 8 7 6 5 4 3 2 1

FIG. 15.

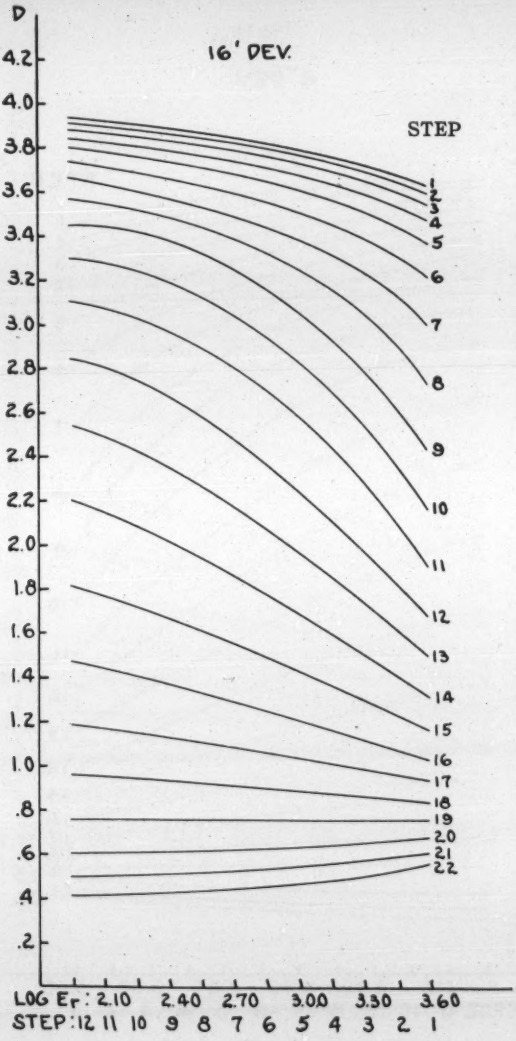
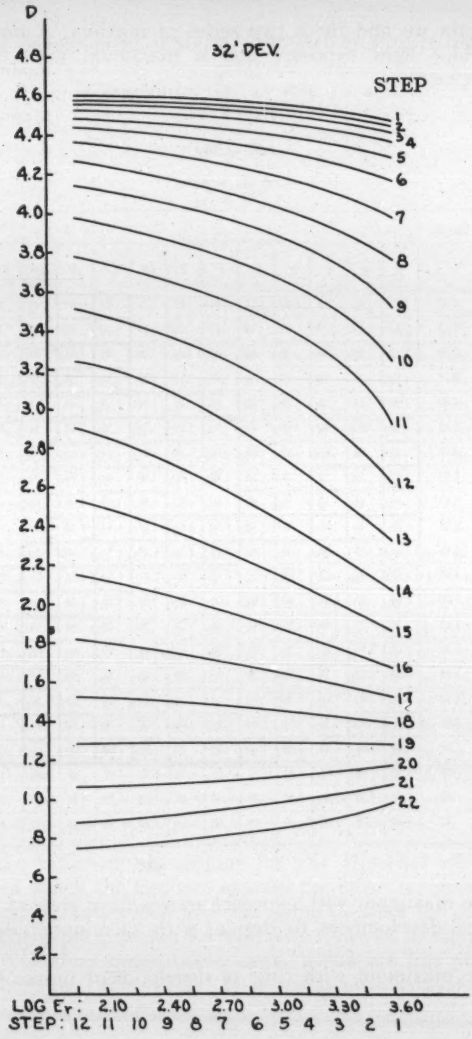

D
16' DEV.
STEP
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
LOG Er : 2.10 2.40 2.70 3.00 3.30 3.60
STEP : 12 11 10 9 8 7 6 5 4 3 2 1

FIG. 16.


D
32' DEV.
STEP
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
LOG E$_T$: 2.10 2.40 2.70 3.00 3.30 3.60
STEP: 12 11 10 9 8 7 6 5 4 3 2 1

Again we find there two series of maxima: A maximum with blue light exposure and a maximum with time of development.

TABLE VI.

$D_b - D_r$.

LOG $E_r = 3.60$.

| Step | Log $E_b$ | 2′ | 3′ | 4′ | 5′ | 6′ | 7′ | 8′ | 10′ | 12′ | 16′ | 22′ | 32′ | Dev. Time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.60 | .12 | .12 | .13 | .16 | .17 | .16 | .17 | .25 | .29 | .32 | .27 | .14 | |
| 2 | 3.45 | .12 | .15 | .19 | .20 | .20 | .19 | .20 | .27 | .30 | .32 | .28 | .14 | |
| 3 | 3.30 | .15 | .18 | .24 | .25 | .24 | .24 | .24 | .29 | .32 | .34 | .29 | .16 | |
| 4 | 3.15 | .18 | .21 | .29 | .30 | .31 | .29 | .30 | .33 | .36 | .37 | .31 | .17 | |
| 5 | 3.00 | .21 | .25 | .35 | .34 | .38 | .40 | .40 | .40 | .43 | .43 | .36 | .21 | |
| 6 | 2.85 | .24 | .28 | .42 | .46 | .49 | .49 | .52 | .55 | .55 | .52 | .44 | .28 | |
| 7 | 2.70 | .25 | .34 | .49 | .57 | .62 | .66 | .70 | .72 | .74 | .66 | .58 | .38 | |
| 8 | 2.55 | .27 | .39 | .55 | .66 | .75 | .80 | .86 | .92 | .93 | .74 | .72 | .51 | |
| 9 | 2.40 | .28 | .41 | .58 | .71 | .83 | .90 | .97 | 1.06 | 1.08 | 1.03 | .88 | .62 | |
| 10 | 2.25 | .27 | .40 | .56 | .71 | .85 | .94 | 1.03 | 1.15 | 1.18 | 1.14 | 1.00 | .74 | |
| 11 | 2.10 | .24 | .35 | .51 | .66 | .80 | .91 | 1.01 | 1.26 | 1.21 | 1.19 | 1.09 | .85 | ←max. |
| 12 | 1.95 | .18 | .27 | .43 | .58 | .71 | .82 | .92 | 1.07 | 1.13 | 1.16 | 1.09 | .90 | |
| 13 | 1.80 | .14 | .21 | .36 | .50 | .60 | .69 | .78 | .92 | 1.00 | 1.04 | 1.01 | .92 | |
| 14 | 1.65 | .10 | .17 | .29 | .39 | .48 | .54 | .62 | .70 | .79 | .88 | .88 | .83 | |
| 15 | 1.50 | .07 | .11 | .20 | .28 | .34 | .39 | .44 | .54 | .58 | .64 | .66 | .67 | |
| 16 | 1.35 | .05 | .07 | .13 | .18 | .22 | .24 | .29 | .36 | .38 | .43 | .46 | .47 | |
| 17 | 1.20 | .02 | .03 | .06 | .08 | .12 | .14 | .16 | .19 | .22 | .25 | .31 | .29 | |
| 18 | 1.05 | .00 | .00 | .02 | .02 | .04 | .04 | .06 | .07 | .09 | .12 | .14 | .12 | |
| 19 | .90 | −.01 | −.01 | −.02 | −.03 | .00 | .00 | .00 | −.01 | .00 | .00 | .00 | .00 | |
| 20 | .75 | −.02 | −.03 | −.04 | −.05 | −.04 | −.05 | −.06 | −.06 | −.07 | −.07 | −.09 | −.11 | |
| 21 | .60 | −.02 | −.03 | −.06 | −.06 | −.07 | −.07 | −.08 | −.08 | −.11 | −.11 | −.16 | −.20 | |
| 22 | .45 | −.03 | −.03 | −.07 | −.07 | −.08 | −.08 | −.10 | −.10 | −.13 | −.15 | −.21 | −.24 | |
| | | | | | | | | | ↑ max. | | | | | |

The maximum with exposure moves from step 11 with 2 minutes' development to step 14 with 32 minutes' development.

The maximum with time of development moves from 2

minutes' development at steps 1–7 to step 18 with 16 minutes' development.

The absolute maximum lies at step 11 with 10 minutes' development.

TABLE VII.

$$\frac{D_r}{D_b} \times 10^3.$$

LOG $E_r = 3.60$.

| Step | Log $E_b$ | 2′ | 3′ | 4′ | 5′ | 6′ | 7′ | 8′ | 10′ | 12′ | 16′ | 22′ | 32′ | Dev. Time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.60 | 898 | 933 | 941 | 937 | 939 | 946 | 946 | 927 | 920 | 919 | 936 | 969 | |
| 2 | 3.45 | 897 | 914 | 914 | 921 | 927 | 935 | 935 | 920 | 917 | 918 | 934 | 969 | |
| 3 | 3.30 | 871 | 895 | 889 | 899 | 911 | 917 | 921 | 913 | 910 | 912 | 931 | 965 | |
| 4 | 3.15 | 842 | 875 | 863 | 877 | 884 | 898 | 901 | 900 | 898 | 904 | 925 | 962 | |
| 5 | 3.00 | 809 | 848 | 831 | 857 | 854 | 857 | 865 | 876 | 876 | 887 | 912 | 953 | |
| 6 | 2.85 | 769 | 823 | 791 | 802 | 808 | 814 | 821 | 828 | 839 | 861 | 891 | 931 | |
| 7 | 2.70 | 740 | 776 | 746 | 744 | 749 | 752 | 753 | 769 | 780 | 820 | 854 | 913 | |
| 8 | 2.55 | 690 | 725 | 698 | 689 | 682 | 689 | 687 | 698 | 715 | 765 | 814 | 880 | |
| 9 | 2.40 | 641 | 685 | 655 | 641 | 628 | 631 | 631 | 639 | 658 | 701 | 766 | 850 | |
| 10 | 2.25 | 597 | 655 | 629 | 608 | 589 | 588 | 585 | 589 | 609 | 654 | 722 | 814 | |
| 11 | 2.10 | 571 | 646 | 611 | 588 | 570 | 562 | 555 | 554 | 571 | 616 | 679 | 775 | |
| 12 | 1.95 | 600 | 667 | 613 | 579 | 562 | 554 | 544 | 541 | 557 | 591 | 653 | 743 | ←max. |
| 13 | 1.80 | 611 | 681 | 613 | 573 | 565 | 560 | 549 | 544 | 553 | 590 | 642 | 716 | |
| 14 | 1.65 | 655 | 685 | 618 | 594 | 579 | 585 | 567 | 568 | 582 | 600 | 646 | 714 | |
| 15 | 1.50 | 708 | 738 | 666 | 632 | 622 | 621 | 617 | 606 | 623 | 646 | 686 | 735 | |
| 16 | 1.35 | 750 | 788 | 718 | 695 | 686 | 700 | 677 | 667 | 691 | 707 | 739 | 781 | |
| 17 | 1.20 | 875 | 880 | 823 | 818 | 773 | 774 | 675 | 771 | 770 | 790 | 789 | 841 | |
| 18 | 1.05 | — | — | 923 | 937 | 900 | 913 | 888 | 891 | 880 | 875 | 882 | 921 | |
| | | | | | | | | | ↑ max. | | | | | |

Three different expressions for the Herschel effect are given, of which the last two express the effect for unity blue light density and which give the same maxima for different blue light exposures and for different times of development. Table VII gives quantitative data, which are less practical than those in Table VIII. It is much more convenient to

express a greater Herschel effect in a higher number than in a smaller number. The percentage formula, therefore, is the most suitable for practical application.

TABLE VIII.

$$\frac{D_b - D_r}{D_b} \times 10^2.$$

LOG $E_r = 3.60$.

| Step | Log $E_b$ | 2′ | 3′ | 4′ | 5′ | 6′ | 7′ | 8′ | 10′ | 12′ | 16′ | 22′ | 32′ | Dev. Time | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.60 | 10.17 | 6.74 | 5.86 | 6.27 | 6.07 | 5.39 | 5.39 | 7.33 | 7.99 | 8.12 | 6.37 | 3.04 | | |
| 2 | 3.45 | 10.26 | 8.57 | 8.64 | 7.94 | 7.25 | 6.46 | 6.45 | 7.99 | 8.33 | 8.18 | 6.63 | 3.06 | | |
| 3 | 3.30 | 12.93 | 10.47 | 11.11 | 10.08 | 8.86 | 8.28 | 7.84 | 8.68 | 8.99 | 8.76 | 6.92 | 3.51 | | |
| 4 | 3.15 | 15.79 | 12.50 | 13.68 | 12.30 | 11.61 | 10.18 | 9.93 | 10.00 | 10.20 | 9.63 | 7.46 | 3.75 | | |
| 5 | 3.00 | 19.09 | 15.24 | 16.91 | 14.29 | 14.56 | 14.29 | 13.47 | 12.34 | 12.34 | 11.31 | 8.76 | 4.68 | | |
| 6 | 2.85 | 23.08 | 17.72 | 20.90 | 19.83 | 19.22 | 17.88 | 17.87 | 17.19 | 16.08 | 13.90 | 10.86 | 6.31 | | |
| 7 | 2.70 | 26.04 | 22.37 | 25.39 | 25.56 | 25.10 | 24.81 | 24.65 | 23.08 | 22.02 | 18.03 | 14.57 | 8.71 | | |
| 8 | 2.55 | 31.03 | 27.46 | 30.22 | 31.13 | 31.78 | 31.13 | 31.27 | 30.16 | 28.44 | 20.73 | 18.56 | 11.94 | | |
| 9 | 2.40 | 35.90 | 31.54 | 34.52 | 35.86 | 37.22 | 36.89 | 36.88 | 36.05 | 34.18 | 29.85 | 23.40 | 14.98 | | |
| 10 | 2.25 | 40.30 | 34.48 | 37.09 | 39.23 | 41.06 | 41.23 | 41.53 | 41.07 | 39.07 | 34.54 | 27.78 | 18.59 | | |
| 11 | 2.10 | 42.86 | 35.35 | 38.93 | 41.25 | 43.01 | 43.75 | 44.49 | 43.46 | 42.90 | 38.39 | 32.06 | 22.49 | | ←max. |
| 12 | 1.95 | 40.00 | 33.33 | 38.74 | 42.03 | 43.83 | 44.57 | 45.54 | 45.92 | 44.31 | 40.84 | 34.71 | 25.64 | | |
| 13 | 1.80 | 38.89 | 31.82 | 38.71 | 42.74 | 43.48 | 43.95 | 45.09 | 31.51 | 44.64 | 40.94 | 35.81 | 28.39 | | |
| 14 | 1.65 | 34.48 | 31.48 | 38.16 | 40.63 | 42.11 | 41.54 | 43.06 | 41.42 | 41.80 | 40.00 | 35.34 | 28.62 | | |
| 15 | 1.50 | 29.17 | 26.19 | 33.33 | 36.84 | 37.78 | 37.86 | 38.26 | 39.42 | 37.66 | 35.36 | 31.43 | 26.48 | | |
| 16 | 1.35 | 25.00 | 21.21 | 28.26 | 30.51 | 31.43 | 30.00 | 32.22 | 33.33 | 30.89 | 29.25 | 26.14 | 21.86 | | |
| 17 | 1.20 | 12.50 | 12.00 | 17.65 | 18.18 | 22.64 | 22.58 | 20.00 | 22.89 | 22.92 | 21.01 | 21.09 | 15.93 | | |
| 18 | 1.05 | — | — | 7.69 | 6.25 | 10.00 | 8.70 | 11.11 | 10.94 | 12.00 | 12.50 | 11.77 | 7.89 | | |
| | | | | | | | | | ↑ max. | | | | | | |

The data given above show that the maximum Herschel effect in these experiments lies at step 11 and 12 with 10 minutes' development. This occurs with a blue light exposure, which gives a density from 2.33–2.60.

SUMMARY.

1. To correct some historical statements concerning its origin and theory the discovery of the Herschel effect is republished.

2. The results of the investigations of A. L. Schoen and R. M. Briggs, who showed that Wratten filter No. 87 is the most suitable for the Herschel effect, are given.

3. The significance of the Herschel effect for the study of desensitizers of the latent image is discussed.

4. It is shown that the Herschel effect shows maximum effects determined by the amount of the first blue light exposure and the time of development.

5. A quantitative expression for the Herschel effect is discussed.

My thanks are due to Mr. R. P. Loveland, who started this investigation with me and made several of the sensitometer determinations published in this paper.

**The Floating Needle Experiment.** F. E. BEACH. (*Am. J. Science*, Nov., 1928.) A needle can be made to float upon the surface of water. It is usual to describe it as resting in a trough in a yielding elastic film, much as a nail would lie on a horizontal sheet of rubber. The author has found this to be untrue. For the floating needle to rest in a trough water must not adhere to the steel, but by touching the needle to a water surface and withdrawing it it is seen that water adheres. It is further said that oiling the needle slightly makes it easier to float. This also the author denies.

When the needle floats, all of it is below the horizontal plane passing through the undistorted surface of the water. On the assumption that the cross-section of the needle is circular, the water surface bends gently downward until it meets the steel surface much above the center of the needle making an angle of nearly 90° with the surface. Most of the needle is in the water below the horizontal plane through the line of contact between steel and water, while a small part projects above this plane into the air.

Owing to the nature of its ends a needle is likely to plunge into the water. A ring 5 cm. in diameter was made from steel wire of a millimeter diameter and could be readily floated when it was quite clean, but it was nearly impossible to make it float after it had been slightly oiled. For quantitative purposes a tube of aluminium 6 mm. in diameter was bent into a closed ring or torus 6 cm. in diameter. It weighed 7.13 grams and the water met it at almost the same angle as it met steel. When clean it floated readily, but it could not be made to float after it was rubbed with oleic acid. The condition that the ring should float is that its weight equal the sum of 3 forces, viz.,

*a*. The upward pull of the bent water surface within and outside of the torus.

*b*. The weight of the water displaced, lying below the horizontal plane through the lines of contact between metal and water.

*c*. The force of buoyancy due to the absence of water from the space over the ring.

Measurements were made and each of these forces was calculated. They were respectively 1.360 gm., 4.720 gm. and 1.196 gm. Their sum was 7.276 gm., which differs by only 2½ per cent. from the weight of the torus 7.13 gm.

When the water surface was dusted with lycopodium powder the torus rested in a trough since the liquid did not wet the metal. Again the sum of the three supporting forces just about equaled the weight of the ring. G. F. S.

# AIRCRAFT DETECTORS AND THE ANTI-AIRCRAFT PROBLEM.

BY

CAPT. H. B. ELY,

Ordnance Department, U. S. A.

THERE are three things in which most civilians feel a proprietary interest—these are the Army, the Navy and the Marine Corps. It is my purpose tonight, in a brief space of time, to describe one of the many phases of activity in which this Army of yours is engaged so that you will have an idea of our problems and how they are solved. There are those who think that Army officers, in time of peace, spend their efforts figuring out how to start a war. That, of course, is as ridiculous as it would be to accuse our doctors of prescribing medicine to cause ill health so as to have plenty of patients, or of accusing firemen of being anxious to have conflagrations and policemen of inciting burglaries, and the like.

The Army, in time of peace, prepares not for war, but *against* war.

Science today is traveling along in what we might call "second gear." The last century science moved slowly but established many important and basic facts. The twenty-five years just past have experienced a shift from this "low gear" of scientific progress. The advances made in radio, television, automobiles, airplanes, textiles, talking movies, and many other mechanical and electrical devices illustrate this point.

I well remember the thrill which I received one day twenty years ago while still a boy but filled with enthusiasm over scientific problems. My laboratory was a table and some shelves in my bedroom where miscellaneous electrical and wireless equipment were set up. A wireless telegraph set had been developed with which I had no difficulty in tuning in many of the code transmitting stations in the vicinity of New York City. A newly purchased silicon detector was a highly prized part of the set, and I desire to state that equipment was much harder to obtain in those days than it is today.

On this day as I listened in, I thought I heard voices, and with a little careful adjustment and tuning I brought up the signal strength to a point where I knew I was listening to a conversation—one of the first of radio telephone transmissions, which I then suspected, and afterward verified, was taking place between Dr. Lee de Forest's Laboratory in the Metropolitan Tower and another experimental station in Newark, New Jersey. I was about ten miles from these two stations.

The next day I was to meet with reverses, however, for the housemaid in making up my bed upset an electrolytic interrupter filled with a sulphuric acid solution, the result being a large hole in the bed spread and another in the bedroom carpet. I do not remember if I was promptly ejected from my laboratory like Edison after his baggage car explosion, but soon after I established my laboratory in a small shanty where the members of the household would not interfere with scientific progress.

From the day of de Forest's audions to the present, radio has developed with amazing rapidity.

Soon we are to shift over again into a period of high powered scientific development such as the world has never dreamed of. Aircraft, television and like items, now in their infancy, will be brought to perform way beyond our greatest hopes.

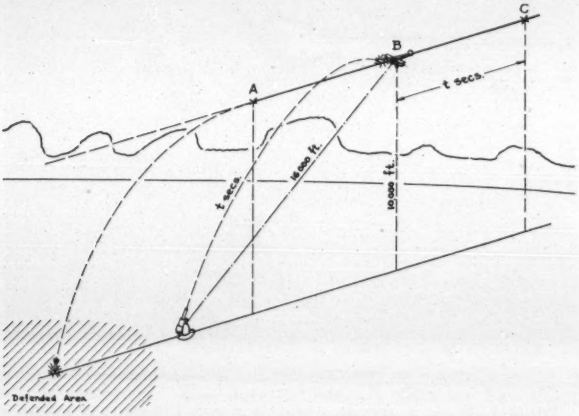
The Army in time of peace must keep up a high grade research program so as to be ready for any emergency that may arise. If the war comes, we must have the best guns, powders, fire control instruments, transportation, aircraft and methods of warfare that it is possible to develop. We are a great research laboratory. Many people think that all one has to do to start a war is to go out, call the men together and go into it. But who is to provide the arms and equipment, the tactical methods, the guns, tanks, optical instruments, sanitary equipment, messing facilities—the myriad of things that go to make up an Army in the field? The foreign armies are keeping up to date, and if we do not, there is a terrific waste of life and money if war comes.

I stood, this spring, on a sand dune at Fort Story on the Virginia coast and watched the firing of a battery of four 16-inch howitzers at a target ten miles away. Each of the rounds

fired weighed 2,000 pounds. The target was about the size of this room and the shots fell close enough to it to have been hits had it been a warship. An error of half a degree in setting the guns would have thrown the projectile off several hundred yards. The mechanism to do this is as complicated as a locomotive and may be even more carefully constructed for the great accuracy required.

By maintaining a modern Army with modern equipment, we may thwart off any desire of a foreign nation to engage us in war. In the last war, it is well known that the Germans discounted at very little the amount that the United States could do. Of course, they were unpleasantly surprised but we might have been saved from the war if we had been known as a prepared nation.

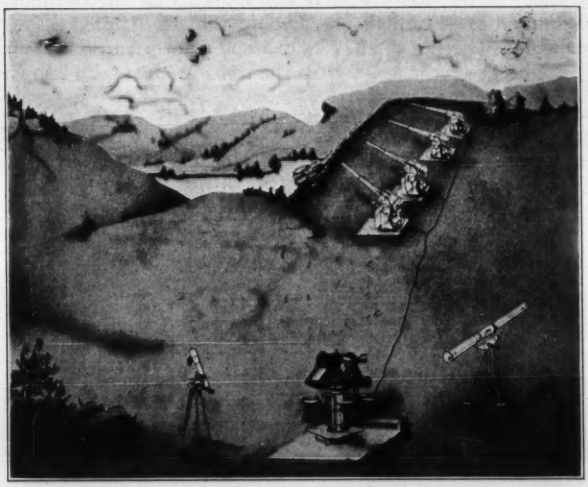
PLATE I.




One of our most urgent problems at present is that of defense against aircraft. The airplane is a small, exceedingly swift target traveling in three dimensional space, and thus has added to previous firing problems the elements of speed and altitude. In three minutes an airplane can come from a distance at which it is a nearly invisible speck to a position overhead from which it can drop its destructive bombs. At

night the plane cannot be seen at all. And here I wish to state that while machine gun fire is used on low flying planes of any class, it is only the bombing plane at high altitudes which it is profitable to attack by ground fire. War must be conducted on a paying basis, and the cost of firing at other than bombing planes, as compared with the worth of the targets and effect, is too great.

PLATE 2.



A battery of anti-aircraft guns with latest fire-control equipment.

Plate 1 shows a diagram of an area to be defended and an airplane flying toward this area. A bomb released at point *A* would strike within the area. An anti-aircraft gun must fire so as to hit the target at some such point as *B* ahead of *A*. If *B* is 10,000 feet high and three miles away, it will take the high explosive projectile fired 15 seconds to reach *B* so that it must be fired when the target is at *C*, the travel of the plane through *BC* being equal to the time of flight of the projectile.

It is evident that the sighting of the target, computation of data, setting and loading of the gun and firing must take place in a very small period of time. A modern battery of four 3-inch A. A. guns can place a barrage of 100 shells on the line of travel of an airplane within two minutes of the first sighting of the plane.

Plate II shows diagrammatically the set-up of a modern battery of A. A. guns. These guns are automatically set and controlled from a remote mechanism called a director, into which is entered the angular travel of the airplane through telescopes manned by two observers. The target altitude is obtained by a height finder and automatically set into the director. Having the course and height of the target, the director computes automatically and instantly the proper predicted setting for the guns. To this are added corrections for the effect of wind, temperature, velocity of the projectile and other ballistic factors, all of which are automatically set into the guns.

The projectiles are loaded and the pieces are fired with a rapidity of 15 to 28 shots per minute for each gun depending upon the caliber. As one looks in the direction of the tiny target, white puffs of smoke are seen indicating the shell bursts all around the objective.

And here I wish to present the description of a future bit of warfare as I am wont to picture it. In the light of recent demonstrations, at the Army Proving Ground, of the rapid strides made in anti-aircraft material, I do not feel that I have over-estimated the possibilities of near future development.

The faint purr of airplanes is heard in the distance, the sound of several planes mingling into one—doubtless an attack squadron. But almost instantly after we have heard the sound, a sharp crack is heard to the flank and this followed in rapid succession by others and still others, and up in the clouds a tiny flash and then a series of flashes are seen. The purring of the airplanes is drowned out by the crack and boom of anti-aircraft artillery. A tiny flaming meteor is seen to drop from where the flashes were seen; another is seen to start at a lower point. The guns cease firing. Silence reigns in the darkness of a slightly cloudy night. No sound of air-

plane is heard nor other sound except those incident to any night in the country.

We have pictured the successful repulse of an air raid of the future by a battery of anti-aircraft artillery, the surprise of a group of aviators who, traveling without light or other visible manifestation of their presence, have found themselves without warning in an inferno of bursting shells with no knowledge that they were even under observation. Some fortunate ones have maneuvered, dropped from the inferno and turned about, their mission unaccomplished. Others have gone the way.

But how were these bursts placed with such accuracy in utter darkness and no visible or audible indication of preparation?

A large amount of our daily activity depends upon sight for its execution; much of our daily pleasure and enjoyment is obtained through seeing things. The artilleryman in war uses his various sights to set his guns upon the target, just as a surveyor sights through a transit or level. The principal activities of mankind are carried on during daylight hours when objects can be seen. But what happens when light fails with the falling of night, or even during light hours when objects cannot be seen by virtue of screening or other diversion of the light rays? The auditory system comes into play to guide us; to warn of the automobile bearing upon us from behind, to warn of the approach of trains, to guide boats in foggy weather, to assist the blind man as he taps along the street with his cane, to tell one from whence this or that sound comes and to warn us on many occasions.

Some people are born with big ears. Science has provided a means of augmenting the auditory powers of others who would hear into the distance. The second in importance of our senses of perception is that of hearing.

The enemy airplane in future wars, approaching under cover of darkness, in fog or in smoke screen, will be heard and located at distances perhaps greater than the ranges of visual instruments in daylight. The sound locator is one of the newest pieces of ordnance and is part of the fire control equipment of a modern anti-aircraft battery. It came into being during the late war in Europe like many other instruments of

war. The old story of the appearance of a new offensive weapon calling for a new means of defense was repeated. The sound locator is a part of the defense used against the airplane, a new and powerful weapon which sprang into existence as a war machine during the last great war and has steadily gained in importance in this capacity. A large part of the mission of the airplane is accomplished at night under the cover of darkness when visual means for detection cease to function. It is then that we turn to our second great sense of perception, which is only sharpened by darkness and the stillness of night, and seek out the thrum of airplane motors and the whir of the propellers by the aid of acoustics. Just as we use telescopes or field glasses to aid the vision in seeing more clearly or more distantly and to determine direction, so we use sound locators to amplify sounds so that we can hear further and to give us the directions of these sounds.

In conjunction with the ears, the sound locator depends for its action on what is called the binaural phase effect, briefly explained as follows:

Sound is a vibratory disturbance in the atmosphere, or other medium, wherein a pressure wave is set up traveling from the sound source in all directions at the rate of 1,100 feet per second. This sound wave arrives at a listener's head and unless he is looking in the direction of emission, it will impinge upon the diaphragm of one ear a fraction of a second sooner than upon that of the other ear. The resulting sensations transmitted to the brain are there analyzed by point of time so that instinct tells the listener that the sound source is at a certain angle to the right or left. If now the listener turns his head the proper amount, the sound wave strikes both ears simultaneously and is analyzed as coming from the front. This ability of the ears and brain to determine direction acoustically is called the binaural sense; the effect of the sound wave on the ears is called the binaural phase effect.

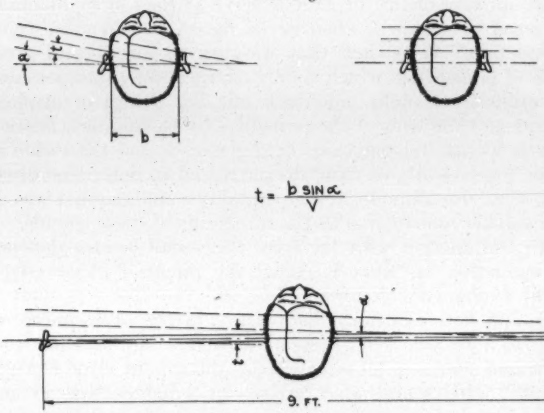
It is evident that if the ears were separated by a greater distance, the difference in time of a sound wave striking one diaphragm over that of the other would be increased and the binaural sense would be sharpened.

Referring to Plate III, if $\alpha$ is the angle of approach of a sound wave and the least value of this which the human ears

can determine is 5° then $t = b \sin \alpha / v$. $t$ equals 40 micro seconds for this value. If we retain this value of $t'$ but lengthen the base line between receivers to 9 feet

$\alpha$ equals 20′ of arc or 1/3°.

PLATE 3.



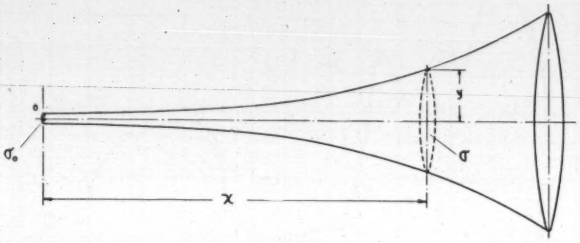

That is exactly what is accomplished by using a sound locator; two large horns separated by a distance, perhaps twenty times that of the ears, are supported always parallel to each other with their small ends terminating at the ears. The sound wave entering both horns travels through each independently until it strikes the ear diaphragms at different instants. The binaural sense immediately tells which way the pair of horns must be swung in order to compensate for the time difference or phase difference. The listener aims to reduce the phase difference to zero at which time his ears will receive the sound impulse "in phase" and the horns will be pointed at the source of sound. The direction can then be read from scales graduated in degrees.

Besides obtaining a greater separation of the receivers by extending the ears through the use of horns, amplification of the sound is obtained by properly designed horns. A horn

upon receiving a continuous series of sound impulses, acts upon these in such a way as to combine their energy and produce a louder sound. There will be losses of energy through reflection and friction but the proper horn design will cut these to a minimum and give the maximum concentration of energy at the small end.

The most efficient type of horn known at present is the exponential horn. The profile of this horn, or its cross-sectional area follows the simple exponential law expressed

PLATE 5.




Exponential horn.

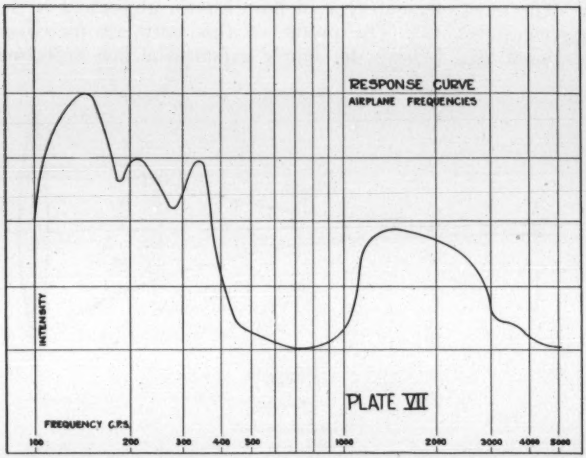
by the mathematical equation $\sigma = \sigma_0 e^{mx}$ where $\sigma$ is the cross-sectional area and $m$ is a constant whose selection determines the rate of flare of the horn. $e$ is the Napierian base 2.718.

This is the type of horn used commercially in a great many sound radiating devices. The latest phonographs use exponential horns, whose lengths are approximately six or eight feet, depending upon the model. These horns are folded up in an ingenious manner in order to place them in suitable cabinets. The talking movies use large exponential horns to reproduce the sounds made by the characters projected on the screen behind which the horns are placed. Many of the best radio loud speakers depend for their faithful reproduction upon the use of exponential horns. Public address systems use these horns.

In the reproduction or collection of sound, it must first be

determined what frequencies, or tones, are to be reproduced, and then design the horn and other equipment to suit these frequencies. If a known band of frequencies is to be dealt with, as in the case of speech or music, then generally the

Plate 7.

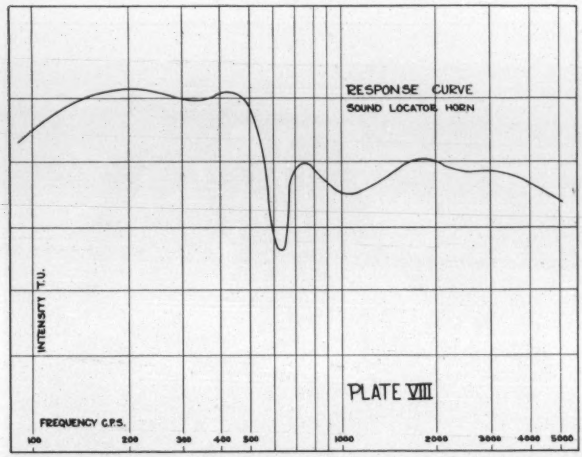



upper and lower frequencies are the determining ones. Formulæ are available for the design of exponential horns so that very faithful, or undistorted transmission through the horn is possible.

In general, the horn becomes larger as we seek to reproduce lower frequencies. A good phonograph horn has a cut-off at about 110 cycles. The sound from an airplane is complex, but much of the energy has a frequency from 100 to 400 cycles. The horns used for its reception have a cut-off around 70 cycles. In this connection, it should be noted that fully half of the sound energy from an airplane does not come from the engine but from the propeller, struts and other unsilenceable parts. The silencing of the engine would not be a handicap in the problem.

The sound locator consists of four large exponential horns mounted on alti-azimuth axes swinging from a seven-foot pedestal. The carriage bearing the pedestal consists of a turntable attached to a pneumatic tired trailer.

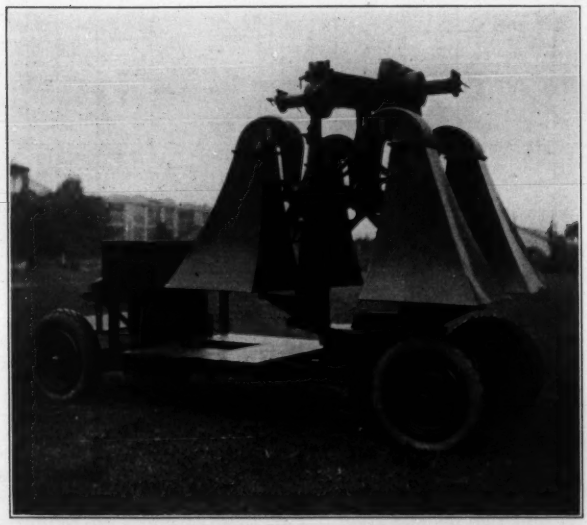
PLATE 8.




The four horns are mounted so as to have their axes always parallel. Two of the horns are used for azimuth determination and two for elevation. Two pairs of horns are required because a sound wave in the region of the sound locator travels approximately as a plane wave, hence is two dimensional. It is then necessary to have a pair of horns for the determination of direction in each of two dimensions at right angles. By means of flexible tubing, the small ends of the horns by pairs are connected with the ears of the operators who control their horns by large handwheels. Due to the concentration required by the listeners, the reading of the scales must be done by additional members of the crew of five or six men found to be sufficient for handling the instrument.

Atmospheric corrections are applied to the readings thus made and the direction angles are then automatically transmitted to gun batteries or other material to be set on the airplane. These automatic data transmitters are among the

PLATE 14a.



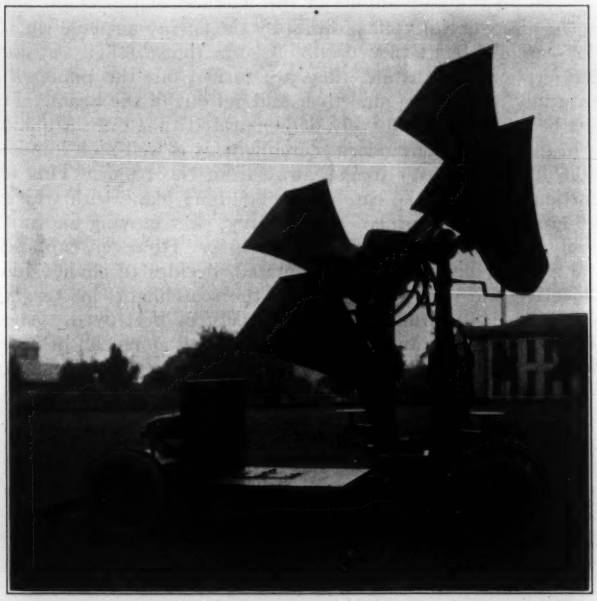
Sound locator with horns in traveling position.

latest and most important additions to the fire control equipment of anti-aircraft batteries, which have to contend with such rapidly moving targets that the making of observations, calculations and setting must be accomplished in the least possible time.

At present the sound locator is used in conjunction with a 60″ searchlight as a finder for the latter. The sound locator and light, separated by a distance of several hundred feet, are connected electrically through a control box called

the comparator. Small synchronous motors transmit to the comparator the angular settings of both sound locator and light. At the comparator also is the remote controller for the light. By using his controller the operator simply keeps two pointers matched whence the searchlight will follow the direction indicated by the sound locator.

PLATE 15.



Sound locator in operating position.

The sound locator has a range of ten to fifteen miles, while the light has a range of five to seven miles. Accordingly, ample time is afforded the listeners to get the plane's course and set the light before the plane comes within range of the

latter's beam. At a given signal the light is turned on and illuminates the plane; in this it is aided by auxiliary lights, the present practice being to have one pilot light and three illuminating lights to a platoon, or two pilots and two illuminating lights. The instant the lights are turned on, the gun battery commences using its visual observation as in the day time. It takes approximately thirty seconds for the gun battery to commence firing after the first observation.

The great disadvantage of this method of procedure lies in the discovery of your position by the enemy airplane when the searchlights are turned on. Assume that the lights strike the airplane the instant they are turned on; the pilot will naturally attempt to maneuver and get out of the beam. It has been quite conclusively demonstrated that once a plane is in the beam of a modern searchlight, it is well nigh impossible for the aviator to get away from the beam. This is particularly so in the case of the bombing plane with which we are chiefly concerned. It is heavy, slow moving and not easily maneuvered from a regular course. However, suppose the aviator, having been illuminated, decides to change his objective and drop his bombs on the searchlight, his target stands out beautifully and might easily be destroyed. The time is not far distant when firing by sound alone can be realized without the give-away of intermediate searchlights. It remains to perfect our aerial sound locating instruments so that accurate enough acoustic data can be obtained for setting guns. Acoustic data will never be as accurate as visual data on account of the differences in the natural characteristics of sound waves and light waves. But acoustic instruments can be perfected to the point where very accurate data are obtainable and the degree of accuracy of these data determined. It then remains for the guns to place a barrage of great enough dispersion to cover the probable error. This is a simple artillery problem.

# THE PROPERTIES OF DIELECTRICS. I. ELECTRIC MOMENT AND MOLECULAR STRUCTURE.

BY

C. P. SMYTH,

Department of Chemistry, Princeton University, Princeton, N. J.

At the request of the Committee on Insulation under the Chairmanship of Dr. J. B. Whitehead, Division of Engineering, National Research Council, a summary of the theoretical aspects of certain of the properties of dielectrics has been prepared. The present contribution aims to present a brief survey of the relations between the electric moments, polarizations, and molecular structures of substances.

Faraday [1] concluded that "the particles of an insulating dielectric whilst under induction may be compared . . . to a series of small insulated conductors" and further concluded that each of these conductors consisted of a single molecule which could be polarized as a whole. When this polarization occurs, one side of the molecule acquires a positive charge and the opposite side a negative charge of equal size, so that the molecule as a whole is neutral. This pair of charges, being at only a small distance apart, may be regarded as forming a small doublet or dipole, the size of which is measured by its moment, the product of either charge by the distance between the two charges. Mossotti [2] treated the idea of Faraday mathematically and Clausius [3] later developed a relation similar to that of Mossotti. Their conclusions are embodied in the so-called Clausius-Mossotti equation,

$$\frac{\epsilon - 1}{\epsilon + 2}\frac{1}{d} = \text{const.},$$

in which $\epsilon$ is the dielectric constant and $d$ the density. The approximate constancy of the expression $\frac{\epsilon - 1}{\epsilon + 2}\frac{1}{d}$, called the polarization, was established for many substances of low dielectric constant, but the polarizations of many substances,

particularly those of high dielectric constant, were found to vary greatly with temperature.

The Lorenz[4]- Lorentz[5] expression for refraction, $\frac{n^2 - 1}{n^2 + 2}\frac{1}{d}$, in which $n$ is the refractive index, is found approximately equal to the polarization in many cases, as would be expected from the well-known Maxwellian[6] relation $\epsilon = n^2$. In many cases, however, when $n$, the index of refraction measured for light in the visible region, is extrapolated to the region of long electric waves in which the dielectric constant is measured, $\epsilon$ is found to be much larger than $n^2$.

Debye[7, 8] has applied to dielectrics a treatment analogous to that used by Langevin[9] in discussing paramagnetism, assuming that a molecule may contain a permanent doublet of moment, $\mu$, which causes the molecule to become oriented in an electric field. The effect of the doublet induced by an applied field is then superimposed upon that of the permanent doublet. Orientation of the molecule containing the doublet is opposed by the thermal agitation of the molecules, which, of course, varies with the temperature, so that the polarization becomes a function of the temperature. Debye has expressed this relation for the polarization of a gram-molecule of a substance, that is, the molar polarization, as

$$P = \frac{\epsilon - 1}{\epsilon + 2}\frac{M}{d} = \frac{4\pi N}{3}\gamma + \frac{4\pi N}{3}\frac{\mu^2}{3kT},$$

in which $M$ = the molecular weight, $N$ = the number of molecules in a gram-molecule = $6.061 \times 10^{23}$, $\gamma$ = the molecular polarizability or the moment of the doublet induced on a molecule by a field of unit strength, $k$ = the molecular gas constant = $1.372 \times 10^{-16}$, and $T$ = the absolute temperature. $\mu^2/3kT$ is the mean component of the moment per molecule in the direction of an internal field of unit strength. As $T$ is the only variable on the right-hand side of the equation, it is evident that, when the molecule contains no permanent doublet ($\mu = 0$), the second term on the right drops out and the equation becomes equivalent to the Clausius-Mossotti expression, which takes account only of doublets induced in the molecules. However, when the molecule is unsymmetrical electrically, containing a perma-

nent doublet, the polarization is a linear function of $1/T$ and the second term on the right may be much larger than the first.

The equation may be written in the form:

$$P = a + b/T,$$

in which $a = (4\pi N/3)\gamma$ and $b = 4\pi N\mu^2/9k$. When $\epsilon$ and $d$ are measured over a range of temperature, the values of the constants $a$ and $b$ may be calculated and the value of $\mu$ obtained from that of $b$. $a$ may also be calculated approximately as the molar refraction for infinite wave-length obtained by extrapolation of the refraction in the visible region. $b/T$ is then given as the difference between $a$ and $P$. This method of obtaining the moment is, at best, less accurate and is misleading when any molecular association occurs.

In the derivation of this equation on the basis of the classical mechanics, it is necessary to suppose that, in the absence of an external field, the molecules are oriented at random. The application of the principle of quantized orientation to the problem led to an equation of the same general form but with a different coefficient for the second term.[10, 11] However, applications of the new quantum mechanics to simple poly-atomic molecules have given equations from which results practically identical with those of the Debye equation may be obtained [12, 13, 14] and Van Vleck [15] has recently given a general proof of the equation on the basis of the new mechanics.

Obviously, when the molecules are not entirely free to orient in an applied field, the equation cannot be expected to apply. For gases, the dielectric constants of which are very close to 1, simplification may be effected by setting $\epsilon + 2$ equal to 3. The validity of this simplified equation has been established experimentally by Jona,[16] Zahn,[17] Sänger,[18] and others.[19, 20] In liquids, the molecules are so close together that large doublets attract one another strongly, forming complex molecules or restricting one another's freedom of motion. The first term of the Debye equation is little affected by the mutual action of the molecules as it is dependent upon electronic shifts within the molecules, but the second term is commonly decreased by lack of freedom of the molecules. However, if the single molecules are

associated to form complex molecules in which the doublets point in the same direction, the second term may be greatly increased. The inapplicability of the equation to certain dipole liquids was shown by Smyth,[21] and Debye [8] and Lange [22] have discussed this effect of molecular association upon the polarization. As molecular association, which usually decreases the polarization, is opposed by thermal agitation, which also decreases the polarization, the polarization of a liquid containing large doublets in its molecules may either increase or decrease with temperature, although the latter behavior is much more common. For example, the polarization of pure ethyl bromide, which has a large electric moment, has been found by Smyth and Morgan [23] to increase slightly with rising temperature, while its solution containing about 5 per cent. hexane has a polarization almost independent of temperature. Solutions richer in hexane, which has no electric moment, have polarizations which decrease with rising temperature, because the ethyl bromide molecules are more separated from one another and, therefore, have greater freedom to orient in an applied field. The molar polarization of the ethyl bromide dissolved in the hexane may be calculated from the total polarization of the mixture and that of pure hexane, and the polarization for an infinitely dilute solution may then be obtained by extrapolation of the values at different concentrations. The polarizations at infinite dilution obtained in this way for ethyl bromide, chloroform, and chlorobenzene have been found [23] to conform to the Debye equation over the entire range of temperature within which the solutions are liquid. Lange's [22] results for nitrobenzene in solution in benzene and in toluene over a shorter temperature range also show conformity to the equation.

The equation of Debye [8, 24] has also been developed in a more general form:

$$\frac{\epsilon - 1}{\epsilon + 2}\frac{M}{d} = \frac{4\pi N}{3}\gamma + \frac{4\pi N}{3}\frac{1}{1 + i\frac{\omega}{\omega_0}}\frac{\mu^2}{3kT}$$

in which $\omega$ is the frequency of the applied field, and $\omega_0$, a

characteristic frequency $= kT/4\pi a^3\eta$, $a$ being the molecular radius and $\eta$, the viscosity. Under ordinary conditions of measurement $\omega$ is so small in comparison to $\omega_0$ that $\omega/\omega_0$ is negligible and the equation becomes identical with the simpler one already discussed, so that the dielectric constants of gases and of liquids of normal viscosity are independent of frequency down to very short wave-length. As the frequency is increased until the wave-length is but a few centimeters, the value of $\omega/\omega_0$ becomes appreciable and rapidly increases with decreasing wave-length. In this region of the electric spectrum the polarization falls off rapidly until it becomes as little dependent on wave-length as the molar refraction with which it is now identical. Mizushima,[25] measuring the dielectric constants of a number of alcohols at wave-lengths of 3.08, 9.5, and 50 m., has found that, for a given temperature, the dielectric constant begins to fall off at a longer wave-length the larger the molecule, while, for a given wave-length, the temperature at which the decrease begins is higher the larger the molecule, and, for a given molecule, the temperature at which the falling off begins is higher the shorter the wave-length. The results are in quantitative agreement with the Debye theory. Similar investigations have been made upon glycerin by Mizushima,[25] Graffunder,[26] and others.

Obviously, when a substance is solid and the molecules are unable to orient in an applied field, the second term should drop out. Substances which possess dipoles in their molecules normally show a great drop in polarization on solidification, after which the polarization shows little variation with temperature.[27, 28] However, Errera[29] reports that the dielectric constants of a number of substances with moments, when measured at wave-lengths of some hundreds of kilometers, show little decrease on solidification and it is only when the wave-length is reduced to about a kilometer or the temperature of the solid lowered far below the freezing-point that the dielectric constant decreases to a value which would make the second term of the equation negligibly small. This seems to indicate that the molecules of a solid near its melting-point possess sufficient mobility to turn slowly in an alternating field.

Attempts[30] have been made to correlate dielectric constant

and chemical composition by treating the constant as an additive property like molar refraction. Thwing [31] assigned values to certain radicals and attempted to calculate the dielectric constant of a substance from the values for the radicals composing its molecule. Walden [32] recognized that certain radicals unsymmetrically distributed in the molecule gave rise to a large dielectric constant, but showed the incorrectness of Thwing's view. As an illustration, he cited the fact that nitromethane, $CH_3NO_2$, had a dielectric constant of 56, from which by Thwing's method the dielectric constant of tetranitromethane, $C(NO_2)_4$, would be calculated to be 104 as compared to the observed value 2.1.

The problem of the relation between dielectric constant and chemical constitution may be more advantageously attacked by applying the modern views of atomic and molecular structure. Faraday's [1] conception of the molecule as a conducting sphere, which led to the derivation of the Clausius-Mossotti expression,[2, 3] must be replaced by the view of the molecule as an arrangement of electrons and positive charges which may or may not be unsymmetrical so as to be approximately equivalent to an electric doublet and which may, when a field is applied, be slightly distorted so as to form a doublet. The theory may be best illustrated by the description of specific cases. The argon atom is believed to consist of a positive nucleus with 18 electrons distributed about it, the total charge of the atom being zero. The symmetry of the distribution is such that the mean position of the center of gravity of the electrons is coincident with that of the positive nucleus, the atom thus having no permanent moment. When the atom is placed in an electric field the electrons shift so that their center of gravity is no longer coincident with the positive nucleus, the system thus forming an electric doublet. Since the molecule contains no permanent doublet, the second term in the Debye equation is zero and the polarization should, therefore, be constant.

The chloride ion, $Cl^-$, is supposed to consist of a symmetrical arrangement of 18 electrons around a nucleus which has 17 positive charges. Since the center of gravity of the electrons coincides with the positive nucleus, the system of charges may, as an approximation, be resolved into a single

negative charge located at the nucleus. If, now, a hydrogen nucleus could, without distortion of the system, be attached to form a neutral hydrogen chloride molecule, a permanent electric doublet should result. The moment of the doublet should be the product of the single electronic charge, $4.774 \times 10^{-10}$ e.s.u., by the distance between the nuclei, which has been calculated from infra-red absorption spectra as $1.265 \times 10^{-8}$ cm. The moment $6.04 \times 10^{-18}$ calculated in this way is far larger than the value $1.03 \times 10^{-18}$ obtained by application of the Debye equation to measurements of the dielectric constant of gaseous HCl, because the positive hydrogen nucleus draws the electrons of the chloride ion toward it distorting the system of charges and greatly diminishing the distance between their centers of gravity. The extent of the distortion has been calculated to be of approximately the right amount to cause the difference between the values of the moments calculated from the molecular structure and those obtained from experimental data.[33]

Although it is impossible, because of the distortion of the electronic systems, to obtain accurate values of the electric moments of molecules from their hypothetical structures, the relative sizes of the moments may often be predicted. Moments have been calculated for a number of substances by applying the Debye equation to measurements of the dielectric constants of gases over a range of temperature.[16, 17, 18, 19, 20] Approximate values[34] have been calculated for the moments of a large number of liquids by the use in a modified form of an equation developed by Gans,[35] who attempted to take account of the effect of molecules upon those immediately surrounding them. Since the equation can now be regarded as, at best, approximate, it need only be stated that its use in modified form provides a means of calculating an approximate value of the moment of a substance from the indices of refraction at two different wavelengths, the density of the substance under the conditions under which these indices are measured, the dielectric constant at one temperature, the density at this temperature, the value of this temperature itself, the molecular diameter, and the universal constants employed in the Debye equation.

Recently, the polarization of a substance at infinite dilution in a non-polar liquid, obtained in the manner already described, has been used with the value of $a$, calculated from optical data, to obtain the moment.[8, 22, 36, 38, 39, 40] The polarizations at infinite dilution which were obtained by Smyth and Morgan[23] in order to test the Debye equation were also used to calculate $a$ and $b$ and obtain accurate values of the moments.

Since most inorganic substances are solids which are insoluble in non-polar liquids, organic substances lend themselves more readily to investigation. Groups which, in inorganic substances, tend to form ions are generally found, on the basis of our hypotheses of molecular structure, to give rise to unsymmetrical arrangements of charges in organic molecules and it is found experimentally that molecules containing radicals such as Cl, Br, I, $NO_2$, OH, etc., contain electric doublets. On the other hand, it has been calculated that a hydrogen atom attached to a carbon may be replaced by a methyl radical without causing any direct change in the electric symmetry of the molecule[34] and this has been confirmed by the experimental fact that all of the saturated aliphatic hydrocarbons investigated, including the nine isomers of heptane, have been found to have no electric moment.[37] Moreover, the aliphatic monohydric alcohols and other homologous series are found to have moments which vary but little with the length of the hydrocarbon chain.[34] The effect of two doublets in the molecule is illustrated by the results of Errera[38] for the geometrical isomers of the compounds represented by the formula CHX = CHX, where X represents a halogen atom. In the cis-form of the compound, in which the two halogen atoms are on the same side of the molecule and the two doublets due to the halogens, therefore, point in the same direction, the electric moment is large, but, in the trans-form, in which the halogens are on opposite sides of the molecule and the two doublets point in opposite directions, the moment is zero. When two doublets are attached to a benzene ring, which is symmetrical and has no moment, they should make an angle of somewhat more than 60° when located in the ortho-position on adjacent carbons, an angle of 120° when in the meta-position separated

by one carbon, and should point in opposite directions when in the para-position. The nitro- and halogen disubstituted benzenes are found to have moments predictable, in many cases quantitatively, on this assumption.[38, 39, 40] Many other relations have been established by Williams and his co-workers,[36] Smyth,[34] and Ebert,[41] who avoided the calculation of the moment and dealt merely with the relation between polarization and molecular structure.

It is evident that the electric moment of a molecule is not a mere mathematical quantity arbitrarily adjusted to make an equation fit experimental data, but a definite physical entity dependent upon molecular structure. Knowledge of the electric moment is helpful in formulating the structure of a molecule, but, what is more important from the practical standpoint, knowledge of molecular structure should make it possible to estimate the magnitude of the moment and obtain dielectrics of desired properties. The dependence of the dielectric constant upon the other properties of the material may be summarized in the statement that the dielectric constant depends upon the number and the mobility of the electrons per cm.$^3$ of material and, when the molecules contain electric doublets, to a much greater extent upon the size and arrangement of the doublets in the molecules, upon the freedom of the molecules to orient, and upon the number of molecules per cm.$^3$.

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# THE INVENTION OF THE MOTION PICTURE.

BY

HENRY LEFFMANN,

Life Member (Honorary) of The Institute.

WHAT constitutes priority in invention or discovery? To what extent must foreshadowings be considered as entitling their utterers to the honors of the pioneer? Aviation is now a well-developed mechanical art: may we date its beginning from Daedalus or find its first step in the *suggestions* of Leonardo da Vinci? Aristotle and Augustin make allusions that may be taken as suggesting evolution: are Darwin and Wallace, therefore, mere followers? A search of Greek literature will bear out Sydney Smith's complaint of "Those confounded ancients who anticipated everybody." Perhaps some enthusiast might regard Paul's "Star differs from star in glory" as an adumbration of modern cosmic spectroscopy.

These musings have been provoked by an article by Mr. George E. Nitzsche, Recorder of the University of Pennsylvania, appearing in the April issue of the quarterly magazine of the General Alumni Society, in which it is frankly claimed that the invention of the motion picture is due to Edward James Muggeridge (familiar in the history of photography as Eadweard Muybridge) working under the auspices of the University and with substantial financial aid from it. Mr. Nitzsche's essay is devoted to demonstrating the validity of this claim and not unnaturally shows much earnestness, which has led unconsciously to a somewhat partisan presentation of the early history of the motion picture. No one person can be credited with the whole or even a vital part of the development of this striking and popular entertainment. As with almost all other great developments in science and art, it is the product of many men in many lands, a slow progression, here a little and there a little, often gaining ground through invention and discovery in apparently unrelated fields. Thus the vogue of the motion picture to-day depends on flexible film, high

speed emulsions capable of retaining sensitiveness for a long time and also of retaining undeveloped the latent image, a powerful light, special projection apparatus, and in the latest phases, high dramatic art. The first bridge built by the Pennsylvania Railroad over the Susquehanna at Havre-de-Grace, bore a tablet stating that it was the work of a thousand men for four years. It may be truly said that bearing in view Heinrich Schulze's experiment in 1727, the motion picture is the product of the labors of hundreds of men for two centuries. Mr. Nitzsche gives a brief statement of the early inventions and methods that were leading up to the present state of the art. It is not necessary to review these statements, except to say that at least two men who did important work are unnoticed. Jules Janssen in 1873 constructed a machine to secure photographs during the transit of Venus in 1874 by which could be recorded the phenomena exhibited at the moment of contact of the planet with the sun's limb. This apparatus, though simple, involved some of the fundamental principles of the modern motion-picture camera, and is described in detail in *Compt. rend.*, 1873, *76*, 678. Another well-known demonstration, not noticed, is that of Friese Greene and Evans, who in the late 80's, exhibited in the window of the shop of the former, a commercial photographer, motion pictures visible to passers-by and created such an attraction that the police authorities requested the discontinuance of the exhibition.

There can be no question of Muybridge's service in applications of photography to the study of the motion of living beings. His pictures startled artists, physiologists, athletes and many others, for they showed that the conventional representations of motion such as a horse running, a man walking or an athlete vaulting, were composites on the brain of the observer, due to the persistence of vision, one image on the retina not being discharged before another is produced. The broad and exclusive claim made in the following paragraph of Mr. Nitzsche's paper cannot be accepted: "After careful study, the credit (of the invention of motion picture) unquestionably would seem to belong to Eadweard Muybridge, whose final researches and experiments under the auspices of the University of Pennsylvania made modern motion pictures possible."

On careful examination of the history of efforts at projection of pictures on a screen so as to give the *illusion* of motion—for that is all that has yet been accomplished in the "movie"—the work of Sellers and Heyl in mid-Victorian years, set forth fully in the literature of this subject is seen to be more closely connected with the line of development than was that of Muybridge. The important point of difference is that Muybridge devised and carried out with great ingenuity and success the *analysis* of motion, but the present day screen-play is a *synthesis*. Muybridge used in his pioneer work a battery of twenty-four cameras so arranged that each was released in rapid succession, thus recording the motion of a living animal in twenty-four phases at very short intervals, but each was an independent picture from a separate point of view, while the series to be commercially applicable must be made, as in the modern work, from one camera, that is from one point of view. A foot note in the University article referring to enormous revenue that would have accrued if the basic patents on the motion picture industry should have been taken out by the Institution is misleading in two ways. The Muybridge method would not have yielded pictures that could have had any widespread vogue, and moreover "if" looms large in the significance of such assertions. The pictures made by Sellers and Heyl, though crude in execution were records of steps in motion, and were taken in such a way that they could be composed and thus give to the viewer the illusion of moving objects which is all that the present day frequenter of motion picture theaters expects. The public at large cares nothing for the analytic data revealed by the camera. In fact the educational applications of the motion picture are entirely secondary to its entertainment features. It is true that in some departments of science, especially in medicine much information has been obtained as to the details of physiologic and pathologic phenomena, but these data remain almost entirely within the professions concerned, or if shown publicly find vogue because they gratify a morbid curiosity.

Sellers' and Heyl's cameras operated interruptedly with considerable intervals between exposures, owing to the slowness of the emulsion then available. They were also

handicapped by the inflexible glass support. The composition of the views in projection seems from reports of those who saw them to have been fairly satisfactory. The most advanced form of motion-picture camera to-day, operates also with intervals, much shorter than those of older days, but this is a difference in degree not in kind. The modern film-maker has the benefit of a dry, speedy, well-keeping, sensitized surface and a flexible film, but in these inventions Muybridge had no share, although he utilized them. For the dry-plate upon which the enormous vogue of photography depends, the world is largely indebted to Doctor Maddox of England and for flexible film largely to George Eastman.

In summing up this study of motion-picture history, it surely appears that, as said above, no exclusive claim can be made for any one, nor is such claim necessary. As Schley said at Santiago, "There is glory enough for all." A long line of workers, only a few of whom sought or secured pecuniary reward, constitutes the group from Schulze down through two centuries that must be honored for their labors. Muybridge is entitled to conspicuous recognition in this series, but in any summary of motion-picture history the work of Coleman Sellers and Henry Heyl must be prominently set forth. There is no justification for declaring Eadweard Muybridge to be the "inventor" of motion pictures.

## NOTES FROM THE U. S. BUREAU OF STANDARDS.*

### NEW INSTRUMENT FOR TESTING PIPETTES.

A NEW instrument, employing a volumetric method, for testing dilution pipettes, has been designed by E. L. Peffer in charge of the bureau's capacity and density section, and constructed in the bureau's shops. The time required to test pipettes by the new method is from one-tenth to one-fifth that required by the weighing method, and the results are of equal accuracy. When it is remembered that 4,200 of these pipettes were tested during the last fiscal year and that for the present year the number will run over 6,000, this constitutes an important economy.

The pipettes in question have a ratio of stem to bulb of one to ten or one to one hundred.

The instrument consists of a small horizontal glass cylinder with double walls. The space between the walls is evacuated to reduce temperature effects and the inner cylinder is filled with a colored non-corrosive solution. Into the two ends of the cylinder project small steel plungers which may be forced into or withdrawn from the cylinder by the rotation of micrometer screws. These plungers are lapped to size and the area of one is ten times that of the other. A dome on the upper portion of the cylinder has an opening with a rubber stopper into which the top of the pipette is inserted.

In making a test, the liquid is driven up the tube of the inverted pipette by the large plunger to the first division, and a reading is then taken on the micrometer. The liquid is then driven through the bulb and to the first ruling on the stem, where a second reading is taken. The small plunger is then used to drive the liquid up the stem, readings being taken at the required points. The volume of liquid displaced by the large plunger being ten times that displaced by the small one, the number of turns and hence the readings of the two micrometers will be equal if the ratio of bulb to stem of the pipette is truly ten to one.

* Communicated by the Director.

The micrometer heads used were taken from ordinary depth micrometers, and are sealed into the glass with Kotinsky's cement. Even with the vacuum jacket there is a slight temperature effect, but this could be reduced by silvering the walls.

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**SOME OLD WEIGHTS STILL VARY WITH CHANGES IN HUMIDITY.**

CERTAIN gold-plated "analytical" weights, tested during the past month, showed such variations with changes in atmospheric humidity, that the desired certificate could not be granted. These weights were at least seven years old. It thus appears to be definitely established that variability of gold-plated screw-knob weights does not necessarily disappear with age. Moreover, the smaller weights in the set showed a slight gain averaging about 0.1 mg. These changes are quite consistent with the idea that the electroplating salts that cause this variability are likely to cause permanent gain also. The necessity for exercising great care in the washing that is necessary after weights are plated, is again emphasized.

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**VISIT OF THE CERAMIC SOCIETY.**

ON the morning of May 4 about 60 delegates from the Ceramic Society of England inspected the bureau's work in the clay products and allied fields.

This visit was part of a tour for the British ceramists arranged by the American Ceramic Society, and which includes inspections of the leading manufacturing plants and research laboratories in the United States and Canada.

The trip through the bureau gave the visitors an opportunity to see the work in progress on clay products, Portland cement, lime and gypsum, stone, and optical glass, as well as related investigations covering the strength and fire resistance of structural materials.

American ceramists have learned much from the long-established ceramic industry of England, where some of the world's most famous chinaware has been manufactured for years. It was therefore particularly gratifying to the bureau to receive this visit and to exhibit some of the apparatus and methods which this country has developed.

## HYDROGEN AND CARBON MONOXIDE IN FLAMES.

An investigation is being made of the relative amounts of hydrogen and carbon monoxide which escape from gas flames in which combustion is nearly complete. Information on this subject, which is of importance in connection with the determination of carbon monoxide and also in connection with efficiency of utilization, has heretofore been based upon very meager data and a somewhat uncertain theory. The determination of the two gases when present in concentrations of a few hundredths of one per cent. is being made by first removing water and carbon dioxide by means of liquid air, burning the reducing gases with the aid of a catalyst, collecting the water and carbon dioxide formed by means of liquid air, and transferring to weighing tubes with a relatively small volume of air.

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## MEETING OF AMERICAN PHYSICAL SOCIETY.

The 157th regular meeting of the American Physical Society was held in Washington, April 18 to 20, inclusive. The meetings on the 18 and 19 were at the Bureau of Standards while that on the 20 took place at the National Academy of Sciences. Because of the number of papers on the program (131) and the limited capacity of the assembly rooms, two sessions were held at the same time in the East and Industrial Buildings of the bureau.

The program covered a vast range of subjects from electrons to interstellar space with a fair number of papers on the application of physical measurements to important technical problems.

The meetings were well attended, the total registration being 321.

The following papers were presented by members of the bureau's staff, and will be published later in the *Physical Review* (University of Minnesota, Minneapolis, Minn.):

Effect of temperature, pressure, and frequency on the electrical properties of rubber. H. L. Curtis, A. T. MacPherson, and A. H. Scott.

The infra-red absorption spectrum of carbon tetrachloride as related to the Raman spectrum of scattered radiation. W. W. Coblentz and R. Stair.

The infra-red absorption spectrum of chlorophyl and xanthophyl. R. Stair and W. W. Coblentz.

Quantitative measurements of wind tunnel turbulence. H. L. Dryden and A. M. Kuethe.

The first spectrum of krypton. W. F. Meggers, T. L. de Bruin, and C. J. Humphries.

Incoherent scattering in Rochelle salt. R. M. Langer.

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**ELECTROPLATING RESEARCHES AT THE BUREAU OF STANDARDS.**

DURING the past few years conferences have been held at the bureau to discuss the progress of researches on electroplating and appropriate subjects for future research by the bureau's staff and by the research associates of the American Electroplaters' Society. This year, at the invitation of the Newark branch and the research committee of the Electroplaters' Society the conference was held in Newark on April 6. O. J. Sizelove of the Newark branch presided at the morning session and R. J. O'Connor, chairman of the Research Committee, at the afternoon session. About 250 persons attended the meetings, at which the following subjects were presented and discussed:

1. *Spotting Out.*—W. P. Barrows, research associate of the American Electroplaters' Society, presented a summary of his investigation of spotting out. The detailed results of this study are now in press, as a Research Paper of the Bureau of Standards, which will appear about June 1. Copies of this paper will be distributed by the Electroplaters' Society to all of its members, and to all subscribers to the research fund.

2. *Chromium Plating.*—A summary of the researches of the bureau on chromium plating was presented by W. Blum, chief of the electrochemistry section of the Bureau of Standards.

3. *Analysis of Cyanide Solutions.*—M. R. Thompson of the Bureau of Standards reported that after many trials very nearly pure sodium and potassium cyanide have been prepared for research purposes.

4. *Measurement of pH in Nickel-plating Solutions.*—Methods of measuring pH in nickel plating solutions were discussed. It is hoped that at the convention of the American Electroplaters' Society in Detroit in July, some definite recommendations may be presented.

5. *Addition Agents in Copper Electrotyping Solutions.*—R. O. Hull, research associate of the International Association of Electrotypers reported on addition agents in copper electrotyping solutions. He explained that when certain addition agents are used, the deposits are smoother and harder than those from solutions with no addition agent. This solution is now being tried on a commercial scale in several electrotyping plants.

6. *Iron Deposition.*—C. E. Thomas, Bureau of Engraving and Printing, reported on a process for the electrode position of iron. This iron has a tensile strength of 4,000 kg./cm.$^2$ (56,000 lbs./in.$^2$).

7. *Future Plans.*—The discussion of future plans emphasized the need for more information regarding the protective value of electroplated coatings against corrosion, as a basis for specifications of quality. It was pointed out that the various tests and specifications for zinc and cadmium coatings are not adequate. It was also stated that although chromium plating has been widely applied in the automobile and other industries, the present methods and specifications do not yield entirely satisfactory products.

It was suggested that in any study of the protective value of electroplated coatings, the Electroplaters' Society and the Bureau of Standards should coöperate closely with committees of the American Society for Testing Materials and similar organizations. The hope was expressed that the automobile industry as well as other metal industries would contribute to the support of such an investigation.

At a subsequent meeting of the executive committee and the research committee of the American Electroplaters' Society, it was decided to have their two research associates undertake a comprehensive study of "Protection against corrosion by means of electroplated finishes." Such a study will probably require about three years. The first subject to be investigated will be the protective value of chromium plating. As soon as possible the plans for the study will be prepared and discussed with interested firms and organizations.

## PROTECTIVE COATINGS FOR PIPE LINES.

THE American Gas Association in coöperation with the Bureau of Standards is starting an investigation of protective coatings for pipe lines. A general study of the nature and method of application of the more common types of coatings is now under way. As soon as this is completed a number of manufacturers will be asked to apply their products to pipe samples, and these samples will be buried in a few locations where the corrosion is known to be severe. Some of the samples will be removed at intervals for examination. Each manufacturer will be expected to meet a general specification as to the nature and thickness of the coating.

Manufacturers of coatings should communicate with the bureau in case they wish to have their product considered in the tests which are being planned.

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## FADING OF DYED TEXTILES IN DAYLIGHT AND IN CARBON ARC LIGHT.

THE American Association of Textile Chemists and Colorists and the Bureau of Standards have been studying the fading of dyed textiles with the primary object of developing standard methods for testing fastness to light. One phase of this work, involving the exposure of over 10,000 individual samples to daylight under various conditions and to carbon arc light, was started in 1926 and has now been completed. A brief outline of the work and some of the results obtained follows. A report by William H. Cady and William D. Appel will be published soon in the American Dyestuff Reporter.

A total of 1,252 specially prepared dyeings on cotton, wool, silk, and weighted silk, representing some 381 different coloring matters, were exposed to daylight in several different ways, and to the light from a glass-enclosed carbon arc. Each sample was exposed for four different periods of time. In general, slight fading occurred in the first period, decided fading in the fourth, and intermediate amounts of fading in the other two. Seven sets of samples, all cut from the original dyeings, were exposed in the following ways: Sets *A* and *K* in the standard sun test of the American Association of Textile Chemists and Colorists, i.e., on clear days between 9 A.M. and

3 P.M., under glass, at an angle of 45 degrees from the horizontal, facing south; set *B*, simultaneously with sets *A* and *K* but with no glass cover; set *D*, continuously, under glass in a vertical position, facing south; set *E*, continuously, under glass, at an angle of 45 degrees from the horizontal, facing south; set *F*, continuously, under glass in a vertical position, facing north; set *G–H*, in the "Fade-ometer," a type of glass-enclosed carbon arc. The results of a sample by sample comparison of the dyeings in the several sets with the corresponding dyeings in set *A* taken as the standard are given in the paper. It is shown that:

1. The "standard sun test" (Set *A* above) of the American Association of Textile Chemists and Colorists gives essentially reproducible results with reference to the relative fading of the dyeings in the series.

2. The presence or absence of a window glass cover over the samples during exposure in the standard test has practically no effect on the fading of 74 per cent. of the samples and only a slight effect on 22 per cent. of them. It has a marked effect on the fading of the remaining 4 per cent. of the samples.

3. Marked divergences in the relative fading of the dyeings in continuous exposures compared with the fading in the standard exposure are noted. These divergences are most marked in the samples exposed continuously, in a vertical position, facing north. A considerable number of the cotton dyeings faded relatively faster than the wool and silk dyeings in this test. In general, the basic dye types, the indigoids, and the ice colors on cotton, fade much faster relative to some other cotton, wool, and silk dyeings in the vertical north exposure.

4. Although the majority of the dyeings fade to about the same extent, relative to one another, in the arc exposures compared with the standard sun exposures (1 arc hour = 1.3 hours in the "standard sun test"), fading in the arc light is different in quality from that in sunlight in many instances. Some samples fade entirely too much, others entirely too little, in the arc exposures, but the agreement between standard sun test and arc test is much better than between the former and the continuous exposure in a vertical position facing north.

Miscellaneous observations on the peculiarities in a behavior of individual dyeings are recorded.

A classification of the dyeings for fastness to light and a selection of standards of fastness will be given in another report.

## STANDARD SAMPLES.

THE renewal No. 30c of the bureau's standard sample No. 30b, chrome-vanadium steel, has been prepared and is ready for distribution. The new sample has the following composition: carbon .490, manganese .71, phosphorus .019, sulphur .013, silicon .236, chromium .971, and vanadium .24 per cent. The price of this standard is the same as that of No. 30b, $3.00 per 150 grams.

## NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

### PHOTO-VOLTAIC CELLS WITH SILVER—SILVER BROMIDE ELECTRODES.[1]

W. Vanselow and S. E. Sheppard.

PHOTO-VOLTAIC cells consisting of silver—silver bromide electrodes in solutions of potassium bromide have been studied. The potential difference—time curve obtained is the resultant of two effects, viz., an initial negative effect on which is superimposed a positive effect. A hypothesis was developed explaining these in terms of the liberation of electrons and bromine atoms from bromide ions on absorption of light. In agreement with this it is shown that the positive effect can be suppressed, the negative effect made more pronounced, by addition of bromine acceptors. The positive effect is shown to be similar to that produced by allowing bromine to diffuse through the silver bromide layer to the silver.

### THE FORMATION OF THIN FILMS OF ORGANIC COLLOIDS BY SPREADING ON MERCURY SURFACES.[2]

R. L. Keenan.

THIN films of cellulose esters, gelatin, rubber, and fatty acids were obtained on mercury when the proper conditions were attained. The method consisted in allowing drops of solutions of varying concentrations to spread on a mercury surface cleaned by the sweeping procedure, the amount of substance being insufficient to cover completely the liquid surface. The film area was developed with talc powder, and

* Communicated by the Director.

[1] Communication No. 362 from the Kodak Research Laboratories and published in *J. Phys. Chem.* **33**: 331. 1929.

[2] Communication No. 363 from the Kodak Research Laboratories and published in *J. Phys. Chem.* **33**: 371. 1929.

measured by a planimeter. On plotting the thickness of the film, calculated by assuming the density equal to the massive material, against concentration, a point is reached at which this thickness value becomes independent of the concentration (or dilution).

The limit thickness increases on passing from rubber through the carbohydrate derivatives to the protein, that is with increasing complexity of the atom groups

| (C, H) | (C, H, O) | (C, H, O, N) |
|---|---|---|
| 1.5 Å. U. | 2.5 – 5.0 Å. U. | 7 Å. U. |

In the case of the cellulose nitrate there appears to be an inverse relation between the viscosity and the thickness of the limit film.

The method and its control were governed by measuring the length of the molecules of fatty acids and other known molecules which were determined by Langmuir and others.

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## ILLUMINATION IN MOTION PICTURE PRINTING.[3]

C. Tuttle.

THE selection of a light source for motion picture contact printing has been a matter of experiment for each particular case. Quantitative data concerning the amount of light available from various incandescent sources should aid in this selection. A knowledge of exposure requirements and laws which determine photographic intensity may prove of value to those engaged in motion picture processing.

Experimental evidence shows that a simple exponential relation exists between the electrical input and the photographic intensity of tungsten lamps. This relation is given for six various lamps representative of types commonly used in printing.

[3] Communication No. 371 from the Kodak Research Laboratories and published in *Trans. Soc. Mot. Pict. Eng.* **12**: No. 36. 1040. 1929.

## A PHOTOMETER FOR THE MEASUREMENT OF LOW ILLUMINATIONS.[4]

L. A. Jones and E. M. Lowry.

IN the manipulation of photographic materials the provision of satisfactory darkroom illumination is of vital importance. With the advent of high-speed emulsions sensitive to all wave-lengths of the visible spectrum, the problem of providing satisfactory illumination in the darkrooms has assumed greater importance and more and more difficulty has been met in obtaining an illumination which is satisfactory from the standpoint of both photographic safety and visual requirements.

The instrument described in this paper was constructed specifically to meet these special requirements of darkroom photometry and in its design careful consideration was given to those fundamental visual characteristics which determine the precision with which photometric readings can be made. Among the advantages which are claimed for the instrument may be mentioned: Observations are made with unobstructed binocular vision under the same conditions which exist when some task is being performed. The size of the test plate and the test spot are such that the visual angle is that giving maximum contrast sensibility at low illuminations. The intensity adjustment is not accompanied by any change in color of the illumination as of necessity must occur when intensity adjustment is made by control of the lamp current.

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## A STUDY OF GROUND NOISE IN THE REPRODUCTION OF SOUND BY PHOTOGRAPHIC METHODS.[5]

O. Sandvik.

GROUND noise is the term ordinarily used to designate the extraneous noises present in a film used for photographic sound recording, or more explicitly, on a motion picture film having a

[4] Communication No. 373 from the Kodak Research Laboratories and published in *Trans. Soc. Mot. Pict. Eng.* **12**: No. 36. 1054. 1929; *Phot. Ind.* **26**: 1325. 1928; Kinotechnik **11**: 47. 1929.

[5] Communication No. 374 from the Kodak Research Laboratories and published in *Trans. Soc. Mot. Pict. Eng.* **12**: No. 35. 1929; *Amer. Cinemat.* **9**: 9. 1928; *Phot. Ind.* **27**: 265. 1929.

uniform deposit of silver, the magnitude of which may be zero or finite. The purpose of this investigation is to determine some causes of the ground noise and to measure its growth with the increase in the number of times which the film has run through the projector. The results show that the amount of ground noise present on clean film base is imperceptible when the amplifier is operated on a grain normally necessary for an average sound record. The results show that no appreciable increase in the noise level is introduced at the various stages of manufacture. There is, however, a considerable increase in the noise during processing, that is, during developing, fixing, washing, and drying, even when these operations are carried out with the utmost care. The results on several samples of film repeatedly run through the projector show that after the first few runs the noise increases linearly with the number of times run.

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## SOME PRELIMINARY EXPERIMENTS IN MEDICAL MOTION PICTURE PHOTOGRAPHY.[6]

C. Tuttle and C. A. Morrison.

AT the instigation of Mr. Hays, President of the Motion Picture Producers and Distributors Association, the Eastman Kodak Company has recently undertaken some experimental work in connection with motion pictures of medical subjects.

While it is too early to state many definite conclusions regarding the progress of this branch of photography, it is felt that a description of our experiments and preliminary conclusions may be of some interest to those engaged in similar work.

The quantity, quality, and direction of lighting for surgical pictures have been considered and some new experimental lighting units have been built.

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[6] Communication No. 375 from the Kodak Research Laboratories and published in *Trans. Soc. Mot. Pict. Eng.* **12**: No. 36. 1022. 1929.

# THE FRANKLIN INSTITUTE.

## STATED MONTHLY MEETING, MAY 15, 1929.

The stated monthly meeting of the Institute was called to order at three-forty P.M., by the President of the Institute, Nathan Hayward. Medal Day celebration was held in connection with this meeting.

The Chairman stated that the minutes of the April meeting had been printed in full in the May number of the Journal of the Institute and that unless there were objection they would be approved as printed. No objection was offered and the minutes were declared approved.

The Chairman then called upon the Secretary, who reported concerning certain phases of the activities of the Institute since the Medal Day meeting of 1928. The Secretary stated that much business had to be transacted during the afternoon and that he could not, therefore, speak at length. He felt, however, that the Institute would be remiss if it did not make grateful acknowledgment of the aid which had been received from friends during the past year. He referred to the bequest from the estate of the late Craig D. Ritchie, a long time member of the Institute, which had finally become available for the needs of the Institute. This bequest amounted to $32,049.86. He mentioned especially the bequest of the late Dean Marion Reilly which, while relatively small, had brought an especial measure of encouragement to the authorities of the Institute. Miss Reilly was a woman of ability and of high standing, and was at the same time a strong mathematician. She was familiar with the workings of the Institute and with its plans. The Board of Managers was therefore happy to be able to regard her bequest as an evidence of her approval of the Institute. The Board has already voted to establish, by means of her bequest, $1,000, the "Marion Reilly Memorial Library in Mathematical Physics," the subject in which Dean Reilly was most interested.

The Secretary also made grateful acknowledgment of the receipt from Mrs. James Mapes Dodge, a tested friend of the Institute, of an amount which doubled the endowment which she had already presented for the "James Mapes Dodge Lecture Foundation" for juveniles. The Institute now has a handsome endowment which enables these important lectures for young people to be given by prominent scientists during Christmas Week.

The Secretary referred briefly to the completion of the Bartol Research Foundation at Swarthmore and the prospects of a distinguished record for that Foundation. He made mention also of the favorable outlook for rapid progress in the scheme for the new Franklin Institute Building and Benjamin Franklin Memorial and Museum.

The President then announced that the award of Medals was the next order of business and stated that all the medals which had been recommended during the present Institute year by the Committee on Science and the Arts would be presented at this time. The exercises in connection with the various medals were then held.

**PROGRAMME.**

| | *Sponsors* |
|---|---|
| Presentation of Certificate of Merit to | |
| MR. GEORGE F. MACHLET | Mr. Wm. C. Wetherill |
| American Gas Furnace Company | |
| Elizabeth, New Jersey | |
| Received by Mr. A. A. Machlet | |
| Presentation of Longstreth Medals to | |
| MR. EDWARD G. HERBERT | Mr. E. W. Smith |
| Atlas Works, Manchester, England | |
| Received by British Consul General | |
| KONRAD JAGSCHITZ, D. ENG. | Mr. J. M. Rusby |
| Mainz, Germany | |
| Received by German Consul General, Consulate General Office, New York City | |
| MR. A. W. MACHLET | Mr. F. V. Hetzel |
| American Gas Furnace Company | |
| Elizabeth, New Jersey | |
| MR. J. F. PETERS | Mr. C. E. Bonine |
| Westinghouse Electric and Manufacturing Company | |
| East Pittsburgh, Pennsylvania | |
| Presentation of Wetherill Medals to | |
| MR. GUSTAVE FAST | Mr. C. D. Galloway |
| The Bartlett Hayward Company | |
| Baltimore, Maryland | |
| MR. W. H. MASON | Mr. M. M. Price |
| Masonite Corporation | |
| Laurel, Mississippi | |
| JOHANNES RUTHS, D. ENG. | Mr. C. E. Bonine |
| Djursholm, Sweden | |
| Received by Royal Vice-Consul of Sweden | |
| Presentation of the Levy Medal to | |
| MR. LODEWYK J. R. HOLST | Dr. T. D. Cope |
| Brock and Weymouth, Inc. | |
| Philadelphia | |
| Presentation of the Clark Medal to | |
| MR. W. H. GARTLEY | Mr. J. S. Rogers |
| Philadelphia Gas Works Company | |
| Philadelphia | |
| Presentation of Cresson Medals to | |
| SIR JAMES C. IRVINE, C.B.E.; LL.D.; F.R.S.; F.R.S.E. | Dr. H. J. M. Creighton |
| St. Andrews, Scotland | |
| Received by British Consul General | |

CHEVALIER JACKSON, M.D.; SC.D.; LL.D.; F.A.C.S. — Dr. Jos. S. Hepburn
Jefferson Medical College
Philadelphia

ELMER A. SPERRY, SC.D. — Dr. Frederic Palmer, Jr.
Sperry Development Company
Brooklyn, New York

Presentation of the Franklin Medal and Certificate of Honorary Membership to
MR. EMILE BERLINER — Dr. James Barnes
Washington, District of Columbia

Presentation of the Franklin Medal and Certificate of Honorary Membership to
CHARLES THOMSON REES WILSON, LL.D.; F.R.S. — Dr. James Barnes
Cambridge, England
Received by Sir Esme Howard
His British Majesty's Ambassador to the United States

**PAPERS.**

"Vocal Physics—Historical Notes." by EMILE BERLINER. Read by Dr. McClenahan.

"Some Thundercloud Problems," by PROFESSOR C. T. R. WILSON, Cambridge University. Presented by PROFESSOR JOHN ZELENY, Yale University.

Adjourned.

HOWARD MCCLENAHAN,
*Secretary.*

(An extended account of the proceedings of this Medal Day meeting will appear in the July number of the JOURNAL.)

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## COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, May 1, 1929.*)

HALL OF THE INSTITUTE,
PHILADELPHIA, May 1, 1929.

DOCTOR THOMAS D. COPE *in the Chair.*

The following reports were presented for first reading:

No. 2844: Pulse Relay.

No. 2884: Work of Mr. C. S. Chrisman in the Gas Industry.

No. 2898: Phelps Time Recording Door Lock.

GEO. A. HOADLEY,
*Secretary to Committee.*

## MEMBERSHIP NOTES.

### ELECTIONS TO MEMBERSHIP.

*(Stated Meeting, Board of Managers, May 8, 1929.)*

RESIDENT.

MR. JAMES DANIEL EVANS, Attorney, Executive Vice-President and Counsel, Merchant and Evans Company, 2035 Washington Avenue, Philadelphia, Pa. For mailing: Haverford, Pa.

MR. JACQUES L. VAUCLAIN, Vice-President, Baldwin Locomotive Works, Philadelphia, Pa. For mailing: Bryn Mawr, Pa.

NON-RESIDENT.

MR. JOHN J. KNOWLTON, Inspection Electrical Engineer, Western Electric Company, Kearney, N. J.

MR. HOLLAND M. MERRICK, Consulting Engineer, 2028 Land Title Building, Philadelphia, Pa. For mailing: P. O. Box 105, Pottstown, Pa.

MR. VICTOR H. SEVERY, Engineer, Gillette-Severy Laboratories, 1845 South Western Avenue, Los Angeles, California.

ADMIRAL ELLIOT SNOW, C.C., U.S.N., Retired, Apt. E, 2, Bryn Mawr Court, Bryn Mawr, Pa.

STUDENT.

MR. WILLIAM DAVID CHAPMAN, Student and Watchmaker, West Philadelphia High School. For mailing: 5042 Locust Street, Philadelphia, Pa.

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## BOOK REVIEWS.

ÉLECTRONS ET PHOTONS. Rapports et Discussions du Cinquieme Conseil de Physique tenu a Bruxelles du 24 au 29 Octobre 1927 sous les auspices de L'Institut International de Physique Solvay. vii–289 pages, illustrations, 8vo, paper. Paris, Gauthier-Villars et Cie, 1928. Price, 60 francs.

Under the general designation of "electrons and photons" the papers presented at the fifth convention of the section on physics of the Solvay International Institute of Physics, which was held in Brussels from the 24th to the 29th of October 1927, are collected in this volume with discussions. Preceded by a portrait of the late and most regretted Professor Lorentz with a eulogy by Madame Curie, the six papers by authors of international renown are as follows: W. L. Bragg—Intensity of reflected x-rays, Arthur H. Compton—Discordance between experiment and theory of electromagnetic radiation, Louis de Broglie—The new quanta dynamics, Max Born and Werner Heisenberg—Quanta mechanics, E. Schrodinger—Wave mechanics, N. Bohr—The postulate of quanta and the new atomistic development. All these papers and their discussions are rendered into French.

L. E. P.

PHYSICS FOR COLLEGE STUDENTS, AN INTRODUCTION TO THE STUDY OF THE PHYSICAL SCIENCES. By A. A. Knowlton, Ph.D., Professor of Physics, Reed College. xix–641 pages, illustrations, 8vo, cloth. New York, McGraw-Hill Book Company, Inc., 1928. Price, $3.75.

Students in science and technology have a perfectly definite object for making as thorough a study of physics as their time, inclination and capacity permit: study physics, they must. In a non-technical course of study there is still the need of the precise guidance in a correct estimation of inevitable material background which is afforded by a sound knowledge of physics. Doctor Knowlton has been actuated by two major considerations in the preparation of the present volume. One is to present the subject in an attractive and stimulating form which will enlist the interest of readers whose chief objective is in the academic studies in a course of arts; the other is to provide a text of university grade in which modern theories and accepted developments are incorporated. With regard to the first specification he has adopted the very natural and only too often neglected pedagogical expedient of making use of what he terms the "soaking-in process." "No topic is treated at all fully on its first introduction. So much, and only so much, is done with it as is required for use at that point. At its next introduction, something further is added to material which has become a part of the mental background of the student through use. This requires some sacrifice of the logical arrangement most satisfactory to one already familiar with the subject but has the teaching advantage of keeping the beginner con-

tinually in contact with the fundamental principles in all fields. The laws of motion, for example, appear early and often; so too do the fundamental electrical relations. Perhaps one might describe this as a cyclic arrangement."

The work is discoursive with many historical references and side lights on the circumstances which surrounded the discovery and evolution of important principles and the subject matter is thoroughly modern. Besides the familiar topics of treatises on physics, there are included an explanation of the usual atomic theory and further on an account of the components of atoms with relation to radio-activity and again an explanation of the structure of the dynamic atom. It is a comprehensive and rarely attractive text which will surely and amply fulfil its purpose, perhaps indeed too amply in arousing an excessive degree of interest among "arts" students in physical science at the expense of the purely academic subjects. L. E. P.

MECHANICS FOR ENGINEERS, STATICS AND KINETICS. By Julian C. Smallwood, M.E., A.M., Associate Professor of Mechanical Engineering, Johns Hopkins University, Member of American Society of Mechanical Engineers; and Frank W. Kouwenhoven, M.E., Instructor of Mechanical Engineering, Johns Hopkins University, Associate Member of American Society of Mechanical Engineers. x–185 pages, illustrations, 8vo. cloth. New York, D. Van Nostrand Company, Inc., 1928. Price, $2.50.

Undergraduate university teaching in engineering courses has assumed conditions somewhat akin to mass production in the industries. Much standardization in the selection of material and its arrangement is necessary to conform to a balanced curriculum and to cover essentials in the allotted time without overburdening the student. Particularly is that true of a key-subject like Mechanics which may be elaborated far beyond the particular course of study in which it is included.

The present volume has been prepared to satisfy the requirements of the average student in the principles of Statics and Kinetics over a period of 60 to 80 class-room hours. Being a fundamental subject which is taught not later than the second year, certain topics which can be considered with subjects coming late in the course are properly omitted. The explanatory value of the solution of numerical problems incorporated in the text will be welcomed by the serious student and provide the needed encouragement in attacking the numerous unsolved problems. Modern writers occasionally have been rather insistent on the use of the term "radial acceleration" rather than "centrifugal force" which the authors use. "Radial acceleration" indeed does not get us very far with those who are in closest contact with it. The volume with its logically arranged well illustrated and skilfully presented subject-matter is a most desirable contribution to engineering teaching.

THE ELEMENTS OF PRACTICAL MECHANICS. By Charles Ranald MacInnes, Ph.D., Professor of Mathematics in Princeton University. vi–131 pages, illustrations, 8vo, cloth. New York, D. Van Nostrand Company, Inc., 1929. Price, $2.25.

With substantially the same subject-matter and prepared with a similar objective, Doctor MacInnes's text represents the accumulated material of many

years of class-work. As in the previously noticed work, it is a labor-economizing device for the benefit of the student. A very ample collection of problems as well as illustrative examples in the text is provided. A notable feature is the development of graphic methods along with analytic processes which the author has found very advantageous. Prepared by representatives of institutions of learning of the highest rank, the scholarship of these works needs no other guarantee.

L. E. P.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Report No. 299. Investigation of Damping Liquids for Aircraft Instruments, by G. H. Keulegan. 24 pages, illustrations, quarto. Washington, Government Printing Office, 1929. Price, ten cents.

This report covers the results of an investigation carried on at the Bureau of Standards with the financial assistance of the Committee.

The choice of a damping liquid for aircraft instruments is difficult owing to the range of temperature at which aircraft operate. Temperature changes affect the viscosity tremendously. The investigation was undertaken with the object of finding liquids of various viscosities otherwise suitable which had a minimum change in viscosity with temperature. The new data relate largely to solutions.

The apparatus consisted of four capillary-tube viscometers, which were immersed in a liquid bath in order to secure temperature control. The method of calibration and the related experimental data are presented in detail.

The viscosity data for the liquids are given in curves in which $\log_{10} \frac{t_\theta}{t_{30}}$ is plotted against temperature, where $t_{30}$ and $t_\theta$ are respectively the times of discharge through the viscometer at 30° C. and $\theta$° C. Except for a correction which is usually small, the following relation holds:

$$\log_{10} \frac{t_\theta}{t_{30}} = \log_{10} \frac{\nu_\theta}{\nu_{30}}$$

in which $\nu_{30}$ and $\nu_\theta$ are respectively the kinematic viscosities at 30° C. and $\theta$° C. The density at 30° C., the coefficient of cubical thermal expansion for each solution, and $\nu_{30}$ are given, together with other data, so that the absolute viscosity may be computed. The accuracy is within 1 per cent.

Report No. 304. An Investigation of the Aerodynamic Characteristics of an Airplane Equipped with Several Different Sets of Wings, by J. W. Crowley, Jr., and M. W. Green. 14 pages, illustrations, quarto. Washington, Government Printing Office, 1929. Price, ten cents.

This investigation was conducted by the Committee at Langley Field, Virginia, at the request of the Army Air Corps, for the purpose of comparing the full scale lift and drag characteristics of an airplane equipped with several sets of wings of commonly used airfoil sections. A Sperry Messenger airplane with wings of R.A.F.-15, U.S.A.-5, U.S.A.-27, and Göttingen 387 airfoil sections was flown and the lift and drag characteristics of the airplane with each set of wings were determined by means of glide tests.

The results are presented in tabular and curve form.

Report No. 306. Full-Scale Wind-Tunnel Tests of a Series of Metal Propellers on a VE-7 Airplane, by Fred E. Weick. 18 pages, illustrations, quarto. Washington, Government Printing Office, 1929. Price, ten cents.

An adjustable blade metal propeller was tested at five different angle settings, forming a series varying in pitch. The propeller was mounted on a VE-7 airplane in the Twenty-Foot Propeller Research Tunnel of the Committee. The efficiencies were found to be from 4 to 7 per cent higher than those of standard wood propellers operating under the same conditions. The results are given in convenient form for use in selecting propellers for aircraft.

R.

THE ARCHITECT IN HISTORY. By Martin S. Briggs, Fellow of the Royal Institute of British Architects. xii–400 pages, 46 illustrations, 12mo. New York, Oxford University Press, American Branch. Price, $3.75.

Who, after having viewed or studied the Seven Wonders of the Ancient World, the columned structures of Greece and Rome, the rugged grandeur of Gothic cathedrals, has not wondered about the mind which conceived these structural entities of stone and mortar and felt that in the lives of these oldtime architects a touch of the romantic might be disclosed after a patient search? For such persons this book will not be completely satisfying. However, that is not the fault of the author but, as the reader will see, is due to the modesty and retiring nature of these ancient architects, suppression of their identity by jealous and envious employers or in some cases, because the work of building was shared equally by a number of master builders.

A rather astounding fact is that there is so little recorded concerning the architects of earlier times. As a result of this, many writers on architecture have concluded that the architect as such did not exist and gave credit for the design of a structure to the person or persons financing the project. The author of this book is of a different opinion and shows in a very logical manner that the available early records do not deny the existence of architects although at that time they were known by other names. In "The Architect in History" Mr. Briggs has done a good job depicting the evolution of the architect. It is interesting to note how much innate ability and how little part social status played in the attainment of success. In this respect the architect may be classed with the painter and the sculptor. Until the beginning of the nineteenth century royal patronage of either the Church or State was the "Open Sesame" leading to success. Much attention has been paid to the quantity and quality of education these architects received and the gradual changes in the type of early training have been traced up through the ages. Undoubtedly the type of edifices erected depended upon the examples copied and studied by the architect in his youth. Beginning with what information is to be had on the architects of Babylonia, Chaldea and Egypt the author follows the varying but gradually increasing recognition of the architect as an individual through the periods of Greek and Roman supremacy, the Middle Ages, the Renaissance in Italy, France and England and the Nineteenth Century in England. In this way a very comprehensive exposition of the subject has been secured, one which pictures the architect a thoroughly human individual yet does not rob him of any deserved glory.

T. K. CLEVELAND.

AN INTRODUCTION TO CRYSTAL ANALYSIS. By Sir William Bragg, K.B.E., D.Sc., F.R.S. 168 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1929. Price, $4.25.

The text of this book is a report of a series of lectures given in 1926 at University College, Aberystwyth. Being intended for a general audience the subjects were treated in a somewhat elementary form. In preparing the material for publication, the treatment has been more extended and more varied. In the welter of publications on colloids it is agreeable to see something about crystals. Study of the intimate molecular structure of crystals dates from a comparatively recent period, Laue's work in 1912 being here given as the starting point. It is well known that Sir William Bragg and his son, W. L. Bragg, have given a large amount of attention to the subject and added a great deal of important and useful information. The principle has been extended to many substances and it appears that, by means of the x-ray, crystal structure may be detected in a large number of organized tissues. The literature of the subject is already very large and increasing rapidly. The author has found that many who are not directly occupied with this line of investigation are yet much interested in its striking and valuable results. He has in this book set forth concisely and clearly the essential features of present day knowledge. This knowledge indicates the wide practical applications that the methods possess, in view of the light thrown on the intimate structure of substances. Special efforts have been made to make clear the phraseology of the subject, as well from the point of view of the old systems of crystallography, as from that of the x-ray methods. It is, indeed informing to compare the modern representations of atomic distribution and association, now so familiar in writings on this subject, with the suggestions as to crystal structure offered in the treatises of the Mid-Victorian era. Yet it would be unfair to deprecate the suggestions then made, for the workers did not have the methods that are now in our hands. Physicists and chemists who desire to keep in touch with the main lines of discovery and practical value of the intimate study of crystal structure will find this book eminently satisfactory. The symbol for the light-wave unit omits the circle over the "A." This is a commendable procedure. The slogan of modern science should be "away with all accented and umlauted letters." They were the product of the perverse ingenuity of the monks of the middle ages.

HENRY LEFFMANN.

RESEARCH PAPER No. 45. Reprint from Bureau of Standards Journal of Research. Methods for Analysis of Petroleum. By E. W. Washburn, J. H. Bruun and Mildred M. Hicks, Chemistry Division. Pamphlet, 22 pages, illustrations, 8vo. Washington, U. S. Government Printing Office, 1929. Price, ten cents.

In the middle of the last century, the principal causes of world trouble were wheat and cotton. The former, generally called by its British name "corn," was the export product of the North and the latter from the South. "Cotton is King" was the slogan of those who formed the Confederate States, hoping that England's demand for their product would assure early interference on their behalf, but were disappointed. Times change. Oil and rubber are figuring largely in diplomatic complications, and the former is giving rise to both domestic and international trouble.

This paper describes the apparatus and methods which have been developed and are being employed in an investigation on "The separation, identification, and determination of the chemical constituents of commercial petroleum fractions" listed as Project No. 6 of American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by John D. Rockefeller. This fund is being administered by the institute with the coöperation of the Central Petroleum Committee of the National Research Council.

H. L.

ELECTRIC LINES AND NETS; THEIR THEORY AND ELECTRICAL BEHAVIOR. By A. E. Kennelly, A.M., Sc.D., Professor of Electrical Engineering, Harvard University. Second edition, revised and enlarged. viii–426 pages, 32 tables, 222 figures. New York, McGraw-Hill Book Company, 1928. Price, $5.

If one pauses to consider, it appears remarkable indeed that our knowledge of applied electricity has expanded and ramified to such an extent that a whole volume alone may be written upon the conductance characteristics of transmission lines.

Writing on such a subject, the author has produced a textbook of great value particularly to students of electrical engineering. Looked upon as a revision of the author's earlier book, "Artificial Electric Lines" this more recent text has been enlarged to include the subject of real lines and the corresponding theories which have been developed in the last decade. Great pains have been taken to start right at the beginning. The introductory chapters show how the properties of electrical transmission lines may be expressed by means of trigonometrical functions. Equations for the simplest type of lines are first developed and those of greater complexity are constructed from these simpler elements. The theory originally worked out for continuous currents now has been extended to alternating currents which involves a large number of complex relations. The author shows in great detail just how these relations, characteristic of alternating currents, have been developed for various transmission systems.

The appendix contains a summary of the various formulas and their derivation as well as a number of problems which tend to aid in the practical application of these derived formulas.

T. K. CLEVELAND.

ALLEN'S COMMERCIAL ORGANIC ANALYSIS. By C. Ainsworth Mitchell, M.A., F.I.C., with numerous collaborators. Volume VII, fifth edition, revised and partly rewritten. xi–869 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, 1928. Price, $7.50.

C. O. A. as it is commonly known to practicing analysts, marches on like the British Grenadiers at Fontanoy, giving us from time to time a newly revised volume. Except as to one contributor out of eleven it has returned to the land of its birth, and the editorial control is now wholly there. The present editor C. Ainsworth Mitchell is widely and most favorably known in the field to which the work is devoted and chemists may be sure that under his supervision all the text will be trustworthy and up-to-date.

The present volume is devoted to the vegetable alkaloids, thus bringing

together in one volume the data on this important subject. The arrangement of the several groups has been somewhat changed from the previous editions, much of the text having been rewritten. A complete classification according to chemical principles not having been practical, an alphabetical arrangement has been followed. This is entirely satisfactory. The alkaloids intimately associated with the applications and uses of foods and drugs are treated in full in special sections and many other alkaloids of less prominence are duly described. Much space is given to the alkaloids of the familiar beverages. It is to be noted that in the initial paragraph of the article on tea, the product is said to be the leaf of the *Thea Chinensis* of the genus *Camellia*, but the proper form is *Thea sinensis* L. and a plant of the genus *Thea* could not at the same time belong to a genus *Camellia*. The intention was probably to say "family Camelliaceae." It is gratifying to see reference to the work of Howard and Stephenson of Washington, D. C. on the microscopy of the important alkaloids.

The volume now offered is a complete treatise on the available analytic data concerning the vegetable alkaloids. To the chemist who has worked in this field it is not merely a work of reference, it is in many places interesting reading. The reviewer regrets that the sole contributor from the United States is only listed as of the U. S. A. All the others are given their "Local habitation," but Mr. Frank O. Taylor, who has furnished a comprehensive and useful contribution on opium and its alkaloids is merely indicated as an inhabitant of the "great open spaces." In the article on opium, by the way, reference is made to a case reported by Swain Taylor, in which contrary to the usual conditions unsymmetric contraction of the pupils was noted in a patient suffering from opium poisoning. This was cited in the celebrated trial of Carlyle Harris in New York City for poisoning his wife. It was offered by the defense through a distinguished physician from Philadelphia. Mrs. Harris had marked symmetric and strong contraction of the pupils. The prosecuting attorney (referring to Taylor's case) asked the witness "Are you aware that in this case, the man had a glass eye?" The witness answered "no." "Well," said the attorney, "that has been proved in this case and you may go back to Philadelphia."

The volume will be welcome to all chemists occupied with drug and food analysis or dealing with toxicologic problems.

HENRY LEFFMANN.

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## PUBLICATIONS RECEIVED.

*Les Méthodes nouvelles en Analyse Quantique.* Mécanique quantique. Mécanique ondulatoire par Julien Pacotte. 139 pages, 8vo. Paris, Librairie Scientifique Albert Blanchard, 1929, price twenty-two francs.

*La Structure de la Lumière*, par Sir J. J. Thomson, O.M., F.R.S.; traduit par R. Fric, avec une préface de M. A. Cotton. 51 pages, illustrations, plates, 8vo. Paris, Librairie Scientifique Albert Blanchard, 1929, price nine francs.

*Réflexions sur la Mecanique Ondulatoire.* Une ancienne théorie dynamique ondulatoire par E. de Camas. 98 pages, illustrations, 12mo. Paris, Librairie Scientifique Albert Blanchard, 1929, price fourteen francs.

*Introduction a une Connaissance Scientifique des Faits Musicaux* par Pins

Servien. 55 pages, 12mo. Paris, Librairie Scientifique Albert Blanchard, 1929, price 7.50 francs.

*The Industrial Development of Searles Lake Brines with Equilibrium Data*, by John E. Teeple, Ph.D. American Chemical Society Monograph Series. 182 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1929, price $3.00.

*Électrons et Photons.* Rapports et discussions du Cinquieme Conseil de Physique tenu a Bruxelles du 24 au 29 Octobre 1927 sous les auspices de l'Institut International de Physique Solvay. 292 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1928, price 60 francs.

*Elementary Differential Equations*, by Thornton C. Fry, Ph.D. 255 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1929, price $2.50.

*An Introduction to Crystal Analysis*, by Sir William Bragg, K.B.E., D.Sc. 168 pages, illustrations, plates, 8vo. New York, D. Van Nostrand Company, Inc., 1929, price $4.25.

*Introduction to College Physics*, by Clinton Maury Kilby. 349 pages, illustrations, plates, 8vo. New York, D. Van Nostrand Company, Inc., 1929, price $3.00.

*Allen's Commercial Organic Analysis*, a treatise on the properties, modes of analysis, and proximate analytical examination of the various organic chemicals and products employed in the arts, manufactures, medicine, etc. Vol. VII. The vegetable alkaloids. Editor, C. Ainsworth Mitchell. Fifth edition, revised and partly rewritten. 869 pages, illustrations, plates, 8vo. Philadelphia, P. Blakiston's Son & Company, 1929, price $7.50.

## CURRENT TOPICS.

**The Production of New Radiations by Light Scattering.** C. V. RAMAN and K. S. KRISHNAN. (*Proc. Roy. Soc.*, A 789.) "In two preliminary papers (*Indian Journal of Physics*) we have recorded the discovery that when monochromatic light is scattered in a transparent medium (be it gas, vapor, liquid, amorphous solid or crystal), the diffused radiation ceases to be monochromatic, and several new lines or sometimes bands (associated in many cases with a continuous spectrum) appear in the spectrograms of the diffused radiation. Further, the new radiations are, in general, strongly polarised. That the phenomenon is entirely distinct from what is usually known as fluorescence is clear from the fact that the effect is observed when both the exciting radiation and the new radiations generated by it are far removed from the characteristic ultra-violet and infra-red frequencies of the medium. Our preliminary studies have proved conclusively that the effect arises in the following way: The incident quantum of radiation is either scattered as a whole, in which case we have the classical scattering, or else is absorbed in part by the molecules of the medium, the remaining part appearing as a scattered quantum. The part absorbed shifts the molecule to a level of energy different from the initial state. The possibility of a process of this kind, in respect of the electronic state of an atom, was first contemplated by Smekal, and figures prominently in the theory of dispersion due to Kramers and Heisenberg, and in the papers of Schroedinger. Our experiments furnish definite proof of the possibility of such processes, and show that they may occur also in such complicated systems as the molecules of a vapour or a liquid or even in a complete crystal."

Further studies of the effect are reported in this paper. By several slow distillations in vacuo the liquids used were made dust-free, the final distillate being in a bulb of 500 or 600 c.c. volume. The radiation from a 3,000 c.p. mercury arc was focused at the center of this bulb. By filters placed in the path of the light the radiation reaching the tube was practically reduced to the 4,358.3 line and its near companions. Rapid plates were used to photograph the spectrum of the scattered light. For benzene and toluene an exposure of 40 hours was required but 25 hours sufficed for carbon tetrachloride, as stronger light was used.

The spectrum of the light scattered by benzene shows 8 modified

lines with wave-lengths longer and 3 with wave-lengths shorter than 4,358.3 Å.U., the length of the most intense wave in the exciting radiation. The longest modified line has a wave-length of 5,026.3 Å.U. and of such waves there are in vacuo 19,877 in the length of one cm. For radiation 4,358.3 there are 22,938 waves to a cm. For these two lines there is a difference of wave-numbers of 22,938 − 19,877 or 3,061. If there were a radiation of wave-number 3,061 its wave-length would be 1/3061 cm. or .000327 cm. and Bell has studied the infra-red absorption of benzene and found a line at .00033 cm. In like manner most of the modified lines of wave-length greater than 4,358.3 for benzene, toluene and carbon tetrachloride are seen to lead to absorption lines in the infra-red that are known already to exist. It is safe to infer the existence of the other lines predicted by this method. Thus we have "a convenient and accurate method in infra-red spectroscopy. In a single spectrogram taken in the visible region we get all in the infra-red frequencies of the molecule simultaneously photographed, and they could be measured much more accurately than with an infra-red spectrometer. The appearance in the scattered spectra of toluene and carbon tetrachloride of modified lines corresponding to several hitherto unknown frequencies of the molecules, in the extreme infra-red region as far as 46 $\mu$, emphasizes the ready applicability of the method especially to regions not accessible to the ordinary infra-red spectrometer."

In the spectra of the light scattered by all three liquids examined there are lines whose frequencies are larger than those of the exciting lines, but they are smaller in number than the scattered lines of smaller frequencies. Such lines of enhanced frequency are particularly conspicuous in the case of carbon tetrachloride. "The appearance of these lines of enhanced frequency proves in the first place the existence in the liquid at ordinary temperatures of some molecules at a level of energy higher than the normal by that corresponding to an infra-red frequency of the molecule, and, secondly, that the incident light induces a return of these molecules to the normal state. That is to say, while most of the molecules taking part in modified scattering are in the normal state and absorb a part of the incident light quantum, thus giving rise to a scattered radiation of smaller frequency, there is also a small number in the liquid, already in the higher level of energy, which under the influence of the incident radiation can be induced to part with their energy by a return to the normal state, thus giving rise to a scattered radiation of correspondingly higher frequency. In the existence of these lines of enhanced frequency we have for the first time a direct experimental proof of *induced emission* of radiation by molecules."

The polarization of both the modified and of the normally scattered lines was studied. All the normal scattered lines are polarized to about the same extent. The modified lines whose frequencies are greater than those of the exciting lines by certain amounts are polarized to the same extent as the modified lines of frequencies less than those of the exciting lines by the same amounts. "The strong modified lines are usually more polarized than the feeble ones."

The intensity of the modified radiation depends upon the wave-length of the exciting radiation. Thus through a direct vision spectroscope the green line from the mercury arc appeared much brighter than the indigo or violet lines, yet the modified lines due to the green line were invisible while those caused by the violet and indigo lines were conspicuous.

Without doubt the discovery of the Raman effect marks a great advance in the study of radiation. G. F. S.

**The Duration of Contact between the Pianoforte String and a Hard Hammer.** D. BANERJI and R. GANGULI. (*Phil. Mag.*, Feb. 1929.) A string 240 cm. long and weighing 16.4 gm. was stretched horizontally, one end being attached rigidly while the other passed over a fixed pulley and supported a heavy weight. The period of vibration of the string was .0356 sec. A ball hung by fine threads so that, when at rest, it just touched the string. This was pulled aside and coming in contact with the string was the striking hammer. The point of impact was focussed on a slide moved with uniform high speed past the slit of a camera. The wave form of the string was photographed and, the period of the string being known, the speed of the slide was found from the fact that the distance from crest to crest was traversed while the string made a complete vibration. Thus the duration of contact was obtained by dividing the speed into the distance from initial to final contact. With the velocity of the plate equal to 76.33 cm./sec. and the striking ball weighing 46 gr. the duration of contact was determined for different distances of the points of contact from the end of the string. In the table $a$ is the distance in cm. from the nearer end and $r$ the duration in secs.

| $a$ (cm.) | $r$ (sec.) | $a$ (cm.) | $r$ (sec.) |
|---|---|---|---|
| 15 | .0262 | 40 | .0432 |
| 20 | .0263 | 50 | .0432 |
| 25 | .0356 | 60 | .0445 |
| 32 | .0369 | 80 | .0511 |
| | | 100 | .0590 |

Both Kaufmann and Das have given a theoretical formula for calculating the duration of contact. The experimental results agree better with the Indian than with the German formula. "During the time of contact, while the struck point follows the movement of the hammer, the shorter portion of the string instead of remaining straight as contemplated by Kaufmann executes its fundamental mode of vibration."

G. F. S.

**The Difference between the Mechanical and the Optical Lengths of a Steel End-Gauge.** F. H. ROLT and H. BARRELL. (*Proc. Roy. Soc.*, A, 789.) Upon the reflection in air of light from transparent surfaces such as glass a change of phase of 180° occurs and the geometrical surface of the glass is coincident with its optical surface at which the reflection takes place. When, however, the reflecting surface is metallic there is an additional change of phase, that varies only slightly with the wave-length of the light. "It has an effect upon optical measurements, where steel gauge surfaces are used as reflectors, which is equivalent to an apparent displacement of the reflecting surfaces from the geometrical surfaces toward the interior of the gauge. In other words light appears to penetrate a metallic surface and is apparently reflected at a plane which is parallel to the geometrical surface." If an end-gauge terminates in lapped steel surfaces that permit its length to be measured by interference methods then its length optically determined is less than its geometrical length by twice the displacement of the reflecting plane, since the displacement occurs at both ends of the gauge.

Let two end-gauges be placed end to end and wrung together. The distance from one end of the combination to the other is the sum of the lengths of the two gauges augmented by the thickness of the wringing film. The authors devised a process of interference measurements by which the optical lengths of six 1/8 inch gauges, single and in combination, were measured, the light of two different neon lines being used. The length of the row of six gauges was measured ten times. "After each measurement the combination was broken down, the gauge surfaces cleaned with the usual mixture of alcohol, ether and ammonia, and then wrung together with a minimum quantity of paraffin oil." With the particular gauges used the optical length of the combination always was less than the 3/4 inch obtained by adding the nominal lengths of the six constituent 1/8 inch gauges. In units of millionths of an inch the largest deficit of the ten determinations was 56.2 and the least 49.0 with light of wave-length 5852.5 A.U. (yellow). With

red light of wave-length 6506.5 A.U. the greatest deficit was 57.7 and the smallest 49.8. The respective means for the two kinds of light were 52.8 and 53.9. The average lengths of single gauges were found by both wave-lengths. In the case of only one gauge did they differ by as much as one millionth inch.

In the National Physical Laboratory the thickness of the wringing film has from experiment been placed at 1/5 millionth inch. By the use of this in combination with the results of the optical measurements cited above the displacement of the reflecting optical surface into the interior of the gauge is calculated to be 3.3 millionths inch whereas Perard and Maudet in France put it at 3.1 millionths. A table is given showing the lengths of separate gauges measured by optical and mechanical methods. In all cases the mechanical length exceeds the optical by about 6 or 8 millionths inch.

G. F. S.

**Elastic Constants of Fused Quartz. Change of Young's Modulus with Temperature.** H. D. H. DRANE. (*Proc. Roy. Soc.*, A, 789.) This paper is not the outcome of a purely academic investigation but presents results obtained in the laboratory of the The Thermal Syndicate, Ltd. "When fused quartz is heated, its elastic constants for stretch shear and bulk change all increase, a sharp distinction in behaviour from that of most other elastic solids. An elastically-stretched fibre becomes shorter upon heating, and a strained torsion member reduces its twist for a given twisting effort."

In measuring Young's Modulus a little rod of fused quartz was fixed at one end. Weights were applied at the other end and the deflections of an attached pointer were read by a microscope. For low temperature the rod was surrounded by liquid oxygen while an electric furnace was used up to 700° C. beyond which it was not possible to make accurate readings. The author has obtained for Young's Modulus the value $6.7 \times 10^{11}$ dynes. sq. cm. Taking the modulus at 15° as unity the values at other temperatures are as follows,—183°, .9695; 100°, 1.014; 400°, 1.0525; 700°, 1.079. Thus the value increases from the lowest to the highest observed temperature, though the rate of increase grows less with rising temperature.

"There remains as a problem the specification of the precise thermal and mechanical treatment necessary to yield a specimen of fused quartz with fixed mechanical and optical characteristics."

G. F. S.

**The Diffraction of Electrons by Crystalline Powders.** M. PONTE. (*Comptes Rendus*, Jan. 14, 1929.) Another similarity between electrons and radiation has been found. Already they have been shown in the United States to be regularly reflected from the faces of crystals and in Scotland to suffer diffraction upon traversing thin films.

A method of crystal analysis depends upon sending a beam of X-rays upon a powdered crystal in which the axis is distributed equally in all directions. The rays are diffracted and symmetrical images are produced on the photographic plate. Similarly now a beam of cathode rays falls on a wire coated with zinc oxide or on an unsupported structure of the oxide. On the plate clear rings manifested themselves. With a voltage of 17,250 applied to the tube their number was about twenty. The dimensions of the crystal calculated from the wave-length to which the electrons were equivalent agree within 2 per cent. with the results furnished by other methods.

The new method makes it possible to study the structure of a crystal by using electrons in place of X-rays and with relatively short exposure and small expenditure of energy. Only a small quantity of the powdered crystal is needed.

G. F. S.

**The Limiting Density in White Dwarf Stars.** E. C. STONER. (*Phil. Mag.*, Jan., 1929.) Some stars have a mean density that is calculated to be much in excess of any density known on the earth. The companion of Sirius has a mass .85 of that of the sun. Its effective surface temperature is 8,000°. From this fact and from its absolute magnitude being 11.3 its radius can be computed and thus its density determined. The resulting density is 50,000 gm./cu. cm. The density of $O_2$ Eridani B is even greater, viz., 98,000. "At the temperatures in the interiors of stars atoms will be highly ionized, and if in white dwarfs the last stages of the process are reached, the atoms being broken up into nuclei and free electrons, there is no immediate difficulty in the existence of high densities. On a naive view as to the "sizes" of electrons and nuclei (with radii some $10^{-5}$ times that of atoms) densities of the order of $10^{14}$ or $10^{15}$ would not be impossible." More careful consideration based on Fermi statistics leads to a formula that expresses the limiting density of a uniform sphere made up of fully ionized atoms in terms of the ratio of its mass to the mass of the sun. According to this the limiting density of Sirius B is $2.8 \times 10^6$.

G. F. S.

**Control of Current in a Discharge-Tube by Means of a Magnetic Field.** R. F. EARHART and C. B. GREEN. (*Phil. Mag.*, Jan., 1929.) In his book, "The Conduction of Electricity Through Gases," Sir J. J. Thomson cites an experiment in which the current in a circuit was varied by applying a longitudinal magnetic field to a spark gap, when it was desired to leave the impressed E.M.F. and other electrical properties unchanged. In continuance of this method of regulation this paper presents the results of a study of the effects of both longitudinal and transverse magnetic fields. The discharge tube was placed between the poles of an electromagnet. The electrodes were made from brass rod. Soon it appeared that the magnitude of the current traversing the gap had much to do with the size of the effect of the magnetic field upon the current strength. Two other factors assist in determining the effect of the field, viz., the distance between the electrodes and the pressure of the gas in the discharge chamber. With the field in the direction of the electrical discharge the increase in current due to the application of a magnetic field is greater with currents across the gap previously small than with those previously large. For example when a field of 1,500 gauss is brought to bear on a current of 3 milliamperes it increases it by 400 per cent., whereas applied to a current 8 times as large the field causes an increase of only 75 per cent.

The effects due to transverse fields are more complicated. In many cases the application of the field causes an increase of current, which reaches a maximum and decreases with further increase of the field. Indeed with fields sufficiently strong the current may be smaller than at first. The effect of reversal disappears with adequate reduction of the gas pressure. In the instance of hydrogen a figure "shows an extreme case where the application of a transverse field of from 300 to 500 gauss extinguished the discharge, while slightly higher fields restored it, and an application of 1,000 gauss more than doubled the current. The application of still higher fields reduced the current finally to the point of extinction and here the extinction was final."

G. F. S.

**The Quantity of Radium Emanation in the Air according to Measurements made on Aircraft.** A. WIGAND and F. WENK. (*Ann. d. Phys.*, No. 13, 1928.) A quantitative determination of the distribution of radium emanation in the air at different elevations will assist in clarifying our knowledge of the causes of ionization in the atmosphere. Up to the present time there have been measurements made in laboratories, in the open air near the earth

and on mountains. In addition samples of air have been brought down for examination and the radioactivity of wires carried by kites and balloons has been studied. In this paper the measurements were carried out by means of airplanes flying horizontally. Thus the mean value for the horizontal layer was effective in producing the readings and the speed of the plane produced a uniform flow of air through the apparatus.

After examination the method of absorbing the emanation in charcoal was rejected in favor of a condensation method. The forward motion of the airplane drove air into a mouthpiece from which it was led into a little cooling tower where it was freed from water vapor and $CO_2$ that might clog the apparatus. Thence it proceeded to a plate condenser, cooled by liquid air, where the emanation was deposited. About 8 kg. of liquid air had to be taken along in a flight. When the desired height had been attained the pilot was directed to proceed at the same level and air was admitted to the condenser for not more than 7 minutes. After landing the emanation was removed and its amount measured. In a single flight three different experiments could be made. The flights were made near Berlin. Five successful ascensions were made on three of which determinations were made at three elevations. The results show clearly a decrease of radium emanation with elevation. For example in one flight at a height of from 550 to 600 m. the emanation, expressed in $10^{-18}$ curies per cu. cm., was 168; at 2,200–2,400 m. it was 24, while for 3,800 m. no emanation was found. In no case was any emanation detected at 2,400 m. or over. Of course the derivation and previous history of the mass of air through which the horizontal flight is made have much influence on the emanation content.

The authors claim that their results prove the radium emanation in the air to be derived from the earth, at least on the days of the flights.

Measurements of emanation content were made also in the physical laboratory of the University of Halle where in one room it reached 13,800 of the units named above. This high value may have been due to the long use of radium in the laboratory. On top of the tower values were obtained six times as large as in the adjacent garden. This was attributed to the smoke of the city in which emanation may have condensed.

G. F. S.

The thirteenth number of the Annalen der Physik for 1928 is interesting from the fact that of its five articles three are by women. The two shorter papers by men come first and are followed by

"Experimental Investigations on W. Ritz's Theory of the Transversal Vibrations of Quadrilateral Plates" by Alice Lemke. This is succeeded by Frida Stadie's discussion of "Problems of Brownian Movements." The final contribution is "On the Magnetic Properties of Cobalt" by Margarete Samuel. In this last paper two rods of cobalt were investigated. They came from different sources, Krupp's Works at Essen and the Kaiser Wilhelm Institute for the Investigation of Iron in Düsseldorf. They contained 1.33 and 1.5 per cent. iron respectively. Unfortunately it was impossible to get cobalt free from iron for the experiments. An attempt made at the Institute to prepare a rod of cobalt from Kahlbaum's powdered metal free from both iron and nickel failed because the resulting rod became porous upon cooling. The outstanding feature of the results is that the two rods differed greatly in their magnetic properties and no thermal treatment was found that could make them agree.

G. F. S.

**Emulsions Showing Chromatic Effects.** R. H. HUMPHREY. (*Proc. Phys. Soc.*, London, Vol. 41, Pt. 1.) Glycerol has a refractive index of 1.467 that lies between the index of benzene (1.502) and that of acetone (1.359). "A stable emulsion of glycerol in acetone may be made by using pyroxylin (1 to 2 per cent.) as the emulsifying agent; such emulsions are milky, the glycerol being the disperse phase." The index of the dispersion medium may be increased continuously by adding benzene which mixes with the acetone. When its index becomes the same as that of the glycerol the emulsion becomes clear. The equality of the indices holds however only for a particular wave-length and when the emulsion is viewed in white light it is this wave-length that gets through. The light transmitted in this case has the color of this one wave-length. The other wave-lengths present in white light are refracted and reflected many times so that the scattered light is of the color complementary to the transmitted light. By the addition of benzene to the emulsion the transmitted color changes from violet through green to orange, with corresponding changes in the scattered light. The addition of acetone makes the transmitted colors return in the reverse order to violet.

"A change of 1° C. causes a perceptible change of the colour, the change being, for a fall of temperature, in the same direction as for increasing proportion of benzene."

G. F. S.

**New Superconductors.** W. J. DE HAAS. (*Naturwissenschaften*, Feb. 1, 1929.) At the meeting of the British Association for the Advancement of Science held last summer de Haas reported on the work done by himself, van Aubel and Voogt at the Cryogenic Institute, Leyden, upon the subject of superconductivity of metals. They examined for superconductivity not only pure metals but combinations of them. Tin and thallium show this property. Combinations of tin with copper, silver or antimony were tried. Antimony-tin and also thallium-bismuth manifested superconductivity. $Ag_3Sn$ lost resistance continuously from 3.4° abs. to 1.3° without becoming superconducting.

It was further sought to find whether combinations of two metals that separately do not possess the property of superconductivity may show it. The atomic weights of gold and of bismuth lie respectively just above and below the atomic weights of the heavy metals that are superconducting. The eutectic of gold-bismuth was found to be superconducting. "The change of resistance is enormous. While at about 2.2° abs. the resistance has still about .7 of its value at room temperature, at 1/20° lower it disappears completely." At 1.5 abs. neither gold nor bismuth is a superconductor.

G. F. S.

**The Production of Electricity by the Torpedo, a Fish.** E. HUGUENARD and A. MAGNAN. (*Comptes Rendus*, Vol. 186, No. 26.) A living torpedo was placed between two horizontal tin plates which were connected to the terminals of a voltmeter that registered very promptly. If then a quick downward push was given to the plate just above the electric organ, the voltmeter indicated perhaps 20 volts, came back to 8 or 10 volts and then went up suddenly to 50 volts or more. The interval between the two maxima was about 1/10 sec. If on the other hand the compression was exerted alongside of the organ there was only a single throw of the needle. With a dead torpedo it is possible to get a single electric discharge though it is less intense than that furnished by the living organism. "All this leads to the belief that in the torpedo there is a combination of an electric apparatus developing an electromotive force under pressure and of an arrangement capable of producing compression at the will of the animal. This seems to be confirmed by the fact that when one provokes the discharge by pinching the torpedo's tail its body appears to grow thicker."

G. F. S.

**Detection of the Isotopes of Lead by the Band Spectrum Method.** S. BLOOMENTHAL. (*Science*, Feb. 22, 1929.) "A few years ago Grebe and Konen found that the lines near 4,250 Ångstroms in the band spectrum emitted by an arc containing uranium lead were sharper than those from an ordinary lead arc, and were displaced .055 Å. units toward the shorter wave-lengths." The author in the Ryerson Laboratory undertook to apply higher resolving power to the same observations. He made photographs of the spectra in the second order of a 21-ft. Rowland grating. The arc of ordinary lead was used, atomic weight 207.2, and again globules of uranium lead of atomic weight 206.1 were attached to copper rods and the arc was struck between them. Three amperes at 220 volts were used and the exposure lasted 15 hours.

"A line for line comparison of our spectrograms, for instance, near the head of the strong 5678.3 Å. band where there is comparatively little overlapping of neighboring series, shows that each line in the band spectrum secured using uranium lead ($Pb_{206}$) corresponds to the long wave-length member of a group of three lines in the spectrum secured using ordinary lead." There is reason for believing these bands to be due to PbO. If this be so, the separation between the lines of $Pb_{208}O$ and those of $Pb_{207}O$ is given by theory to be .37 wave-number whereas by measurement it is .43.

This spectroscopic method enables lead to be resolved quantitatively into its isotopes, and furnishes results in accord with Aston's analysis.

G. F. S.

**The Foucault Pendulum of the Peabody Museum of Yale University.** C. S. HASTINGS. (*Am. J. Science*, August, 1928.) Since Foucault in 1858 by the use of his pendulum demonstrated the rotation of the earth without reference to any body outside of the earth's atmosphere, his apparatus has come to be an attractive feature of museums. It has been believed that only exceeding long pendulums can be used. This paper is to prove that a moderate length suffices and that the Foucault pendulum can be made an instrument of precision.

A pendulum started to swing in a plane continues to swing in this plane without regard to the rotation of the point of support. If the pendulum were started to swing from a support vertically over the North Pole, the earth would rotate while the plane of vibration remained as at first, so that the plane would appear to rotate above the earth though in fact it would be the earth that rotates with respect to the unchanging plane. Since the earth

rotates through 360° in 24 hours, the plane would apparently turn through 15° per hour. For other places the hourly angle of apparent rotation is 15° multiplied by the sine of the latitude of the place. In the Peabody Museum the length of the pendulum was limited to 35 ft. by the construction of the building. The two usual methods of supporting the pendulum, by gimbals and by a hook whose point rests on a hard steel plate, were rejected in favor of clamping an elastic wire firmly at the top. The bob consisted of a lenticular mass of 28 lbs. of lead. The form was chosen to reduce air resistance and the wire was as fine as it could be with safety. Twice the weight of the bob would break it. The amplitude of the swing from end to end was 22 inches. As time passed the apparent path of the pendulum changed from a straight line to an elongated ellipse. This was remedied by adjustments made at the suspension at the top, so that for eight hours the ellipse failed to interfere. "The time can be read from the dial (over which the pendulum swings) with greater precision than from a sun dial." Measurements of the position of the plane of oscillation were made every hour from 9 A.M. till 4 P.M. on four days. From these it was calculated that in one hour of sidereal time the plane turned through $9.903° \pm .002$. From this the latitude of the Museum was computed to be $41.312° \pm .016$. "The true latitude, as measured directly from the Yale Observatory is 41.311°. Thus the final conclusion is that the pendulum has determined the latitude with an error of only 0.4 of a statute mile with an expectation of error that is not more than twice as great. This is far more accurate than ordinary sextant determinations at sea." The course of the pendulum brings out clearly the difference between solar and sidereal time. This suggests to the author to ask to what extent physical measurements could be used to replace astronomical observations. If no heavenly bodies could be seen on account of such clouds as surround other planets we could still prove the rotation of the earth by the Foucault pendulum, locate the equator and find the latitude of a place. From a study of latitudes the spheroidal shape of the earth would be shown.

G. F. S.

**Scientific Notes from the Books and Letters of John Winthrop, Jr. (1606–1676). First Governor of Connecticut.** C. A. BROWNE. (*Isis*, No. 36.) "The outstanding figure in the history of science in America during the seventeenth century is John Winthrop, Jr., obtainer of the Royal Charter of Connecticut and first Governor of this colony from 1659 to 1676, founder of Ipswich, Saybrook, New London and other New England towns, member of the Royal

Society, promoter of colonial industries, soldier, pioneer, lawyer, statesman, physician, philanthropist, man of business and lover of science." No less than 270 books from his library are preserved in the Society Library, New York City, while his papers and correspondence are in the Massachusetts Historical Society. From these sources the author derives the justification for according so high a place to the subject of his memoir. John Winthrop, Jr., was graduated from Trinity College, Dublin and in 1625, was admitted to the bar in London. He then travelled widely on the Continent where he made the acquaintance of men of science with whom he later corresponded in Latin. In 1631 he sailed for Boston which had been established by his father a year earlier. His library of 1,000 volumes came to him in America and grew in size until his death in 1676. The nature of his books indicates the range of the owner's interests. Of his scientific library 52 books are on chemistry or alchemy, 33 on medicine, 10 on physics, 9 on astronomy, 8 on mathematics, 8 on natural history, 3 on navigation, while a dozen more have to do with geography, metallurgy, military science, agriculture and political economy. Of the 300 of his books still preserved 133 are in Latin, 23 in German, 17 in French, 12 in Dutch, 7 in Italian, 4 in ancient Greek, 1 in Spanish and 71 in English. He had Comenius' "Janua Linguarum Reserata" with its parallel columns giving dialogues in Latin and again in the vernacular.

His chief scientific interest seems to have been chemistry. "His scientific friends in England and in Europe kept sending him books and book catalogues. This is shown, for example, in an old bill submitted by his friend, Francis Kirby, in March, 1633 (the first recorded bill for a shipment of chemicals and chemical apparatus to America), at the bottom of which is mentioned the sending of 3 book catalogues." Among the Winthrop books is George Starkey's "Nature's Explication and Helmont's Vindication." Starkey was a graduate of Harvard in the class of 1646 and was the first American college graduate to publish a treatise on chemistry, the book just named. Winthrop had "Das Buch Meteorum" in its medley of German and Latin, Cologne, 1566, and the "Baderbüchlein," Mühlhausen, 1562, that bears the autograph "Johannes Dee 1562." Winthrop himself attests under date of 1640 that this signature and other material added to the book were "written by that famous philosopher and chemist John Dee with his owne hand."

On the practical side Winthrop tried to establish in New England chemical industries in iron, salt and gunpowder. His papers abound in references to tar, potash, indigo and pitch. In his

handwriting there is a proposal for the formation of a joint stock company for the manufacture of saltpeter, the first prospectus of an American industrial company. His chief chemical interest, however, lay in the application of the science to medicine. He seems to have made no charge for his remedies and doctored all from Indians to governors. According to Cotton Mather "wherever he came, the diseased flocked about him as if the healing Angel of Bethesda had appeared in the place." His main chemical remedies were saltpeter, iron, sulphur, antimony, tartar, copperas, white vitriol and calomel. He prescribed in addition red coral, powdered ivory, rosin, saffron, sassafras, aloes, balsam and rhubarb. He used a secret alphabet to conceal the nature of his medicine for ague and small-pox.

Winthrop was much interested in astronomy, having at his service a 3½ foot telescope. With this he saw 5 satellites of Jupiter, according to a letter he wrote to the President of the Royal Society. Later he donated the instrument to Harvard. He had Kepler's treatise "De Stella Nova," Tycho Brahe's "Astronomicae instauratae mechanica," as well as less famous works in the same field of science.

He collected fossils, ores and minerals, "operated mines in New England for the production of ores of iron, blacklead and other minerals." Indeed he appears to have been the precursor of those who unite a knowledge of mining engineering with executive ability in public affairs. Among his correspondents were Kepler, Newton, Cromwell, Helmont, Milton, Wren and Prince Rupert. In his letters from or to members of the Royal Society such subjects are discussed as the tides, the manufacture of pitch and tar, the refining of gold, deep-sea sounding and meteors. Not only was he a member of the recently established Royal Society but his grandson became one of its Fellows. At the time of the Revolution a third John Winthrop, descended from a brother of the subject of this article, was Hollis Professor at Harvard and a Fellow of the Royal Society.

G. F. S.

**Stellar Radiation Measurements.** E. PETTIT and S. B. NICHOLSON. (*Astrophys. J.*, Vol. 68, No. 4.) The thermocouples used were made of bismuth and of an alloy of bismuth with 5 per cent. of tin. The wires from which the junctions were made had diameters of only .03 mm. "The weight of a compensated thermocouple with two electrically opposed junctions, provided with receivers half a millimeter in diameter, including connecting wires, is about

0.1 mg. The mass of the receiver which is heated by the star is only 0.035 mg. From the electrical properties of the circuit it can be shown that a galvanometer deflection of 1 millimeter corresponds to a rise of temperature of 33-millionths of a degree Centigrade in the receiver. For the giant star Betelgeuse, which is radiometrically the brightest we have measured, the rise in temperature of the receiver is 15-thousandths of a degree; and for the radiometrically faint dwarf, Boss 4342, whose visual magnitude is 7.9, the rise is only 9-millionths of a degree."

A study has been made of 124 stars. The radiation in calories received per minute on a square cm. outside of the earth's atmosphere is from Betelgeuse $132 \times 10^{-12}$, from Sirius $145 \times 10^{-12}$, from Spica $48.5 \times 10^{-12}$, from the sun 1.93.

G. F. S.

**The Transmission of Ultra-Violet Light through Tracing Cloth.** C. H. YOUNG. (*Nature*, Jan. 12, 1929.) At McGill University the effect of ultra-violet light on different kinds of blue print paper was examined. It was discovered in this connection that the ultra-violet light from a quartz mercury vapor lamp passed to a surprising extent through tracing cloth or linen. Reproductions are given of spectrograms obtained with three secs. exposure. The smallest wave-length transmitted by the cloth varied with its make from 2,535 to 2,482 Ångstrom units. Newspaper transmitted no radiation shorter than 3,984 Å.U., while the limit for writing and for wrapping paper was 3,125 Å.U.

The thickness or number of meshes of the cloth per inch appeared to have but little to do with its transmission. It was further discovered that "the heat from the sun or from a red-hot ball passed through the tracing cloth to a much less extent than through glass or vita glass. Herein may lie the usefulness of this discovery, because, whether in sunlight or in artificial ultra-violet light, it is now possible to screen off much of the heat and yet retain most of the ultra-violet. A single layer of tracing cloth, between wide-meshed wire screens, can now replace curtains or blinds, and with this screen before an open sunny window it is possible to enjoy the advantages of ultra-violet light without undue heat or glare, although the eyes should be protected. Moreover, for country cottages, chicken farms, etc., it is now possible to obtain a cheap and effective substitute for the many glasses which have been manufactured to secure ultra-violet light in the more beneficial regions of the spectrum."

G. F. S.

**An Investigation of Pyroelectricity and of Piezoelectricity.** A. MEISSNER. (*Naturwissenschaften*, Jan. 11, 1929.) A circular disc of quartz, 15 mm. in diameter was prepared, its faces being perpendicular to an electrical axis. This was brought into vibration by the application of high frequency currents. Lycopodium powder was used to mark the vibrations. From a study of the results joined to a consideration of their implications it was possible to calculate the distances separating the silicon atoms in the quartz. Thus the distance from a silicon atom to its neighbor in the same plane was computed to be 4.9 Å.U., while from it to another atom of the same element above it the distance was 5.44 Å.U. These results agree well with those obtained by the use of X-rays on the quartz. "There comes out the surprising fact that from experiments made on an object of considerable size structural dimensions of the order of $10^{-8}$ cm. could be determined to an accuracy of a few per cent."

G. F. S.

**The Diffraction of Electrons by a Ruled Grating.** E. RUPP. (*Zeit. fuer Physik*, Vol. 52, p. 8.) Previous investigations of the diffraction of electrons have used crystal structures as gratings. Naturally the question arose whether artificially ruled gratings would serve also to produce the same effect. The experiments cited below give an affirmative answer to the inquiry. A beam of electrons falls at almost grazing incidence upon a grating of speculum metal with 1,300 rulings per cm. The regularly reflected beam is caught upon a photographic plate which is found to record diffracted beams up to the third order. The electrons came from barium oxide. They passed through three slits in series, fell upon the grating and from it went on to the plate. About 40 photographic records were made, there being three different angles of incidence with the grating and three distinct velocities of the electrons determined by the voltage through which they fell. Reproductions of 6 photographic impressions are presented. The entire apparatus was in a vacuum.

The consistency of the results was carefully examined. de Broglie has given a formula for calculating the equivalent wave-length of electrons from their mass and velocity according to which the wave-length is inversely proportional to the velocity. When the electron beam is diffracted by the grating another formula connects these 5 quantities, viz., order of the diffraction band, equivalent wave-length of the impinging electrons, grating constant, angle between the incident beam and the plane of the grating and, finally, the angle between the regularly reflected beam and the

diffracted beam. The wave-length was varied by changing the difference of potential through which the electrons fell. From the formula by the insertion of the other observed quantities the angle between the incident beam and the grating plane was calculated. The values computed from different groups of observations agree within a few per cent. Another type of comparison shows again close agreement between de Broglie's formula and the diffraction formula.

This paper forges another link in the chain that is binding electrons and waves together.

G. F. S.

**Distilling Water by the Heat of the Sun.** J. RICHARD., Director of the Oceanographic Museum at Monaco. (*La Nature*, March 1, 1929.) In regions without fresh water but near the sea it is of great advantage to be able to use the heat of the sun for distilling water from the available salt water. This paper discusses a simple arrangement for doing this.

Inside of a gardener's cold-frame the lower surface of the slanting panes of glass are often covered with drops of water due to the condensation of the water vapor coming from the soil and plants within when it comes in contact with the glass cooled by the outer air. These drops run together and make their way down the inclined glass surface finally dripping away from its lower edge. The government of Tunis instituted a competition for the production of potable water in the south of this country. Maurain then directed attention to the method referred to which seems to have dropped out of sight. It had been used in Salinas near the port of Antofagasta, in the desert of Atacama, Chile. Here the water to be distilled contained 140 gr. of salts per liter, five times as much as in Mediterranean Sea water. 60 wooden frames were installed, each 200 ft. long and 4 ft. wide. The total glass surface was 51,400 sq. ft., the panes being inclined 10° to the horizontal. A gutter for collecting the condensed water ran along the lower edges of the sheets of glass. A windmill pumped the salty water into the frames. Under favorable conditions in summer more than 5,000 gallons or 22 tons of distilled water were thus obtained daily. With the use of the frames a gallon cost less than one cent whereas the cost was four times as much when the water was vaporized by the use of fuel. The result was accomplished with simple materials, wood, glass and putty chiefly.

A similar frame installed in Paris produced 1,083 gr. per sq. m. on a fine day of Sept., 1926, when the sun shone for 7 hours. It was noted that distillation went on even during the night. The

author tried the plan at Monaco on the Mediterranean and in Sept., 1927, got 2,452 gr./sq. m. Ginestous had taken up the observations in Tunis and got on Aug. 23, 1927, 4,043 gr. per sq. m. Inside of his frame the temperature rose to 68° C. Richard has set up at Monaco a small frame with an area of little more than a square m. and with it has made observations of the quantity of water condensed on fine days in every month of the year except January. The greatest production occurred in May and June and the smallest in December, the ratio being about 6 : 1. Days that seem equally fine often produce quantities of water differing by 10 per cent. or more.

When the sun shines more water is obtained with thin glass than with thick. On a certain day a frame with glass 8 mm. thick produced 1,561 gr. while another with glass only 3 mm. thick collected 1,651 gr. On dull days the thicker glass makes the better showing. Reference is made to Ginestous' installing a practical frame in the southern part of Tunis.

G. F. S.

**Diffraction of Cathode Rays by Mica.** SEISHI KIKUCHI. (*Japanese J. Physics*, Vol. 5, No. 2.) Homogeneous beams of cathode rays with energies ranging from 10 to 25 kilovolts passed through thin sheets of mica and fell upon photographic plates about 15 cm. behind the crystal. Diffraction patterns were produced on the plates the form of which depended on the thickness of the mica sheets. With a sheet having a thickness of the order of $10^{-5}$ cm., so thin that it showed no interference colors at all, cathode rays of wave-lengths of .047 and .067 Å.U. respectively gave patterns containing many scores of spots. "These figures consist each of an array of spots forming an equilateral triangular network, the dimensions of the meshes depending on the wave-length. The general feature of the pattern is very little affected by the orientation of the crystal. When a magnetic field is applied on the path of the rays between the crystal and the photographic plate, the pattern displaces as a whole and there can be no doubt that it is due to the cathode rays scattered by the crystal." By using the equivalent wave-lengths of the cathode rays employed the distance between two neighboring molecules in the mica was calculated to be 5.18 Å.U., whereas the same distance according to X-ray analysis was 5.17 Å.U. By varying the potential used in the cathode ray tube the equivalent wave-lengths were made to vary from .0432 to .1032 Å.U. yet the distance calculated remained constant within the error of the experiment. The mica

was so thin that it contained in its thickness only about 50 planes and the diffraction was a two-dimensional one. With greater thicknesses of the mica patterns similar to those obtained by Laue with X-rays diffracted by crystals were produced. Some patterns are very complicated. In these cases the diffraction was due to arrays in three dimensions of the diffracting centers.

G. F. S.

**The Penetration of Hydrogen into Metal Cathodes and its Effect upon the Tensile Properties of Metals and their Resistance to Repeated Stresses.** F. C. LEA. (*Proc. Roy. Soc.*, A. 791.) In many processes of industry pickling is used with resulting brittleness in the metal. This has been attributed to occluded hydrogen. Considerable work has already been done in this field. In this investigation hydrogen is forced into pieces of metal by making them the cathodes in electrolysis. By examination of the specimens thus treated some light on the failure of metals under stress is obtained. For experiments on tensile strength cylinders of metal 2 in. in length and .399 in. in diameter were prepared. These were made the cathodes in either acid or alkali electrolytic baths. Specimens of mild steel were unchanged in tensile strength after the current had deposited hydrogen upon them, but the flow of .25 ampere for 10 min. causes the elongation in per cent. to drop from 38 to 25. The same type of effect was found also for commercially pure nickel and for rustless steel with 26 per cent. of chromium and nickel. In the case of the two kinds of steel electrolysis made a large difference in the area at the time of fracture. Before the deposition of hydrogen the "Reduced in area per cent." was roughly twice as great as afterwards. The type of fracture also was modified. It was discovered that the finish of the surface greatly affected the results. "The tensile strengths of the specimens were the same as the turned specimen; the elongations per cent. and the reductions in area were almost exactly the same as the specimen tested in air." The types of fracture were, however, widely different. Nickel plating mild steel seemed to do away with the effect of electrolysis on tensile strength and other static properties though it lowered the resistance to repeated stresses. A very interesting result was got by subjecting an unplated, unpolished specimen to electrolysis and by subsequently putting it in boiling water for ten minutes. The specimen thus treated reverted in all respects to the characteristics of steel on which hydrogen had not been set free.

"Hydrogen in the cathode does not diminish the resistance to

impact of mild steel and its effect on repeated stress seems of itself unimportant. The fractures under repeated stresses, however, show that the penetration of hydrogen has an important bearing upon the nature and form of fracture of a plastic material, which under torsional repeated stress, fails in a manner similar to quenched and tempered materials.

"Nickel plating mild steel lowers the range of repeated stress but this is not apparently due to occluded gases. As drawn nickel bar is as resistant as mild steel under repeated stresses, it would appear that either initial stresses set up by the deposition or the discontinuity between the metals or, more likely, a crack which early forms in the deposited nickel, is the cause of the lowering of the repeated stress range."

G. F. S.

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